CORANGAMITE CMA

HEALTHY CATCHMENTS - HEALTHY WATERWAYS



Environmental Flow Determination for the Gellibrand River

ISSUES PAPER

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EarthTech

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Ross Hardie	Geomorphology
James Kaye	Riparian vegetation
Lisa Roach	Hydraulic modelling
John Sherwood	Estuarine processes

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Greg Williams	Corangamite Catchment Management Authority
Steve Nicol	Department of Sustainability and Environment
David Blythe	Wannon Water
Cameron Welsh	Southern Rural Water

The Advisory Group consisted of:

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Acronyms/Abbreviations Used in this report:

BE	Bulk water Entitlements
CMA	Catchment Management Authority
CCMA	Corangamite Catchment Management Authority
CRC	Co-operative Research Centre
DSE	Department of Sustainability and Environment
EVC	Ecological Vegetation Class
FEM	The Flow Events Method
FLOWS	The "Statewide Method for Determining Environmental Water Requirements"
ISC	Index of Stream Condition
LWD	Large Woody Debris
MW	Melbourne Water Corporation
SRW	Southern Rural Water
Technical Panel	The Gellibrand River Environmental Water Requirements Technical Panel
VRHS	Victorian River Health Strategy

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Executive Summary

The Corangamite Catchment Management Authority (Corangamite CMA) has commissioned Earth Tech Engineering Pty Ltd (Earth Tech) to undertake an investigation to determine the environmental water requirements for the Gellibrand River catchment.

The Gellibrand River, located in southwest Victoria, flows through significant areas of intact native vegetation. The river is a source of water for towns including Warrnambool, Colac and other Western District townships as well as providing for agricultural activities including dairy, stock and domestic use. Within the catchment the abundant remnant habitat is of importance to aquatic and terrestrial fauna while in the mid and lower reaches of the Gellibrand River catchment, ongoing threats such as modification to physical form, loss of riparian vegetation, willow invasion and sedimentation are of concern.

The investigation involves the use of the Statewide FLOWS method for determining environmental water requirements. This Issues Paper forms Stage 2 of the FLOWS method, proposing draft ecological and flow objectives.

The Issues Paper is the combined result of a review of literature relating to waterway condition in the Gellibrand River and expert opinion following a 2-day field inspection of the nominated reaches of the Gellibrand River catchment. This combined knowledge results in discussions on waterway issues related to water quality, macroinvertebrates, fish, geomorphology and vegetation. Estuarine processes of the lower reach of the Gellibrand River are also discussed, however as this does not form a component of the FLOWS methodology, flow objectives for the reach are not set.

The physical shape and form of a stream is a fundamental component of the stream system. The shape and form of a stream may have inherent values as a consequence of rarity or may have values in the protection and maintenance of related processes such as provision of deep pools for fish habitat.
Maintaining or enhancing the channel morphology of the Gellibrand River is primarily dependent on the effectiveness of high flows through to overbank flows. If the size and duration of these flows were changed significantly, the ability of these flow components to maintain channel morphology will be reduced.

The key to protection of stream shape and form, will be the maintenance of the duration and frequency of the range of flows that do most work on the stream system. These range from mid bank height to the regular overbank flooding events.

Flow recommendations must also consider maintaining or improving the macroinvertebrate community to meet SEPP objectives. This objective requires ensuring a baseflow will sufficiently inundate the major habitats for macroinvertebrate production. The baseflow requirements for the Gellibrand catchment is mainly to keep the bed damp, so a minimal depth of flowing water would be required.

In reaches with adequate riparian vegetation, the major basis of the in-stream food chain is derived from organic material from outside of the stream channel. Dissolved organics, leaves and twigs that are washed from vegetated benches in the channel and from the floodplain are therefore essential to maintain macroinvertebrate communities. Higher flows that inundate benches and overbank flows that wash organic material into the stream are a further important component of any flow regime for macroinvertebrates.

For non-migratory fish species, it is necessary to preserve flows that allow for the redistribution of populations following low flow periods. The natural rise in water level, particularly during Transitional Low to High Flow period is important to allow the movement of individuals, thus mixing the populations and allowing fish to recolonise vacant habitats. Suitable flows for this shall be derived from the depth of water over critical shallow areas in the reach, allowing fish passage.

Maintaining or improving the quality of instream and riparian vegetation requires an integrated approach to on-ground management practices in conjunction with the vegetation's flow requirements. Instream vegetation within this catchment is best supported by constant low flows although some vegetation will tolerate temporary drying. Generally, the base flow should be sufficient to inundate the major habitats for instream vegetation. Pool habitats will not necessarily require constant flow because vegetation will be inundated with varied flow throughout other periods. Low flows will support the requirement of a variety of instream vegetation.

Environmental and flow objectives were developed for the maintenance, restoration and rehabilitation of the Gellibrand River catchment to address the issues identified by the Technical Panel. They include the following key environmental objectives:

- **Physical Form** Maintain or enhance the current channel morphology of the Gellibrand catchment.
- **Fish** Maintain or restore self-sustaining populations of native fish species.
- **Macroinvertebrates** Maintain macroinvertebrate communities to meet SEPP (Waters of Victoria) objectives for AUSRIVAS, SIGNAL, minimum number of families and number of key families.
- **Vegetation** Maintain and where possible enhance vegetation quality ensuring ongoing reproduction, regeneration and seed dispersal .

1 Introduction

Corangamite CMA has engaged Earth Tech to undertake an assessment of environmental flow requirements for the Gellibrand River catchment. The environmental flow assessment is being undertaken in accordance with the FLOWS method – an established approach for the determination of environmental water requirements in Victoria (DNRE, 2002).

The FLOWS method assists in the identification of critical flow components, as part of the total flow regime, to protect, sustain or restore specific flow dependent assets or values. The key elements of the FLOWS process include:

- An objective setting process that links environmental objectives to flow objectives and recommendations.
- The use of an environmental flows Scientific Panel.
- The use of hydrologic and hydraulic analysis tools in the interpretation and development of recommendations (DNRE, 2002).

It is important to note that this environmental flow assessment does not directly address non-flow related issues impacting on river health and management.

The Issues Paper has been developed following the production of a Site Paper and forms part of the FLOWS method. The Site Paper provides background information on the Gellibrand River including literature review, catchment descriptions, historic land use, water use, broad condition descriptions and recommended reaches for the investigations. The Issues Paper has been developed based on detailed literature review and field assessments, provides information on relevant flow related issues in the Gellibrand River catchment and provides draft ecological and flow objectives for identified reaches of the river. **This Issues Paper should be read in conjunction with the Site Paper**.

Format of Issues Paper

Reports on stream geomorphology, hydrology, water quality, aquatic ecology, riparian vegetation and the estuarine issues are provided as appendices to this report. The remainder of this report provides a summary of these findings and preliminary integrated flow objectives on a reach by reach basis.

Hydrologic modelling (REALM) undertaken prior to this environmental flows process defined a number of sites throughout the Gellibrand River catchment. Site reference numbers from this process are correlated to the reach numbers referred to in this report, as summarised in the table below.

Environmental flow reaches and relevant REALM modelling site location

Reach No.	Environmental Flow Reach Name	Environmental Flow Reach Extent	Relevant REALM model site number and name
1	Love Creek Catchment	Love Creek to confluence with Gellibrand River	Site 4 – Love Creek
2a	Upper Gellibrand River (A)	Headwaters of the Gellibrand to Lardner Creek	Site 9 – Gellibrand River (upstream of Lardner Creek)
2b	Upper Gellibrand River (B)	Gellibrand River to confluence with Carlisle River	Site 7 – Mid Gellibrand River (downstream Love Creek)
3	Carlisle River Catchment	Carlisle River to confluence with Gellibrand River	Site 5 – Carlisle River
4	Gellibrand River Mid Reach	Confluence with Carlisle River to Great Ocean Road	Site 8 – Lower Gellibrand River (downstream Kennedy's Creek)
5	Kennedys Creek	Kennedys Creek to confluence with Gellibrand	Site 6 – Kennedys Creek
6	Gellibrand River Estuary	Great Ocean Road to River mouth	Site 3 – Lower Gellibrand River (u/s gauge 235224)

2 Relevant Policies and Strategies

This environmental flow determination study draws upon the Victorian Government White Paper, 'Securing Our Water Future Together' (DSE, 2004), and the Victorian River Health Strategy (DNRE, 2002), to provide broad targets for the Gellibrand Catchment, including the Gellibrand River and its major tributaries Love Creek, Carlisle River and Kennedys Creek. These guidelines assist in defining long-term river health targets that can be met through flow modifications for the river and its tributaries.

The White Paper states *the Government will significantly improve the health of Victoria's rivers, floodplains and estuaries by 2010 to ensure that they are capable of delivering a wide range of services to the community* (DSE, 2004). One initiative aimed at achieving this goal is the Environmental Water Reserve (EWR), a bulk water entitlement specifically for the environment. The volume allocated takes into consideration a sustainable limit on diversions to ensure the environmental values are protected and maintained with adequate flow. (DSE, 2004).

The focus of the environmental flow study is to retain and/or reinstate as many of the features of the natural flow regime as possible. These include:

- Restoration measures to improve water quality, habitat and flows in rivers and wetlands
- Reconnecting floodplain and river linkages
- Building capacity to manage Environmental Water Reserves (DSE, 2004).

3 Broad Environmental Objectives

Broad environmental objectives for the Gellibrand River and its tributaries have been developed based on literature review, research, field inspections (12 October and 4 November 2005) by the Technical Panel and Advisory Group feedback (refer to Appendices for detail). Reach specific objectives have also been developed and are detailed in Section 4.

The broad environmental objectives are:

Physical Form

Environmental Objectives for Physical Form
Maintain and protect the current channel morphology of the Gellibrand River catchment and in particular limit channel encroachments and pool infilling to protect geomorphic values and related assets.

The physical shape and form of a stream is a fundamental component of the stream system. The shape and form of a stream may have inherent values as a consequence of rarity or may have values in the protection and maintenance of related processes such as provision of deep pools for fish habitat.

Maintaining or enhancing the channel morphology of the Gellibrand River is primarily dependent on the effectiveness of high flows through to overbank flows. If the size and duration of these flows were changed significantly, the ability of these flow components to maintain channel morphology will be reduced.

Recent research (Tilleard 2001, Earth Tech 2004) has identified the importance of the total energy expenditure of (or work done by) events that exceed the threshold of motion of the weakest of the bed and bank material, in the maintenance of the physical shape and form of stream systems. Total energy expenditure (or work done by) streams comprises the product of an attribute of work (sediment transport, velocity, shear stress or unit stream power) and the duration of such events over the long term. Further and more particularly Tilleard (2001) found that modification of the effective discharge (the flow unit that does the most work) can have a significant impact on channel capacity.

There is limited research on the extent to which the flow regime can be modified before significant changes in stream morphology become apparent and start to impact on other stream attributes (channel encroachments, loss of pools resulting in reduction in habitat volumes). The work of Tilleard (2001) suggests that on alluvial streams any change to the effective discharge will have an impact on channel size. However it is clear that different stream types will have different robustness to hydrologic change before changes in physical form become evident. Stream systems confined by bedrock in the bed and banks, and systems with low sediment loads will be relatively robust against channel change in response to hydrologic change, when compared against more sensitive systems such as unconfined alluvial streams. The robustness of the alluvial systems will be increased by the presence of intact and recovered instream and riparian vegetation.

The key to protection of stream shape and form, will be the maintenance of the duration and frequency of the range of flows that do most work on the stream system. These will range from mid bank height to the regular overbank flooding events.

While much of the Gellibrand River is confined within the uplands of the Otway Ranges with significant geological controls on channel morphology, there are extensive floodplain areas and floodplain pockets through the system. These will be subject to channel change as a result of changes to the flow regime. As a consequence there will be a need to maintain the frequency of the mid bank to overbank flows to close to natural to preserve intact channel morphology. More importantly with the establishment of the Otway National Park, there will be increasing importance to the protection of remnant floodplain pockets within the region. These will serve as examples of intact systems and can also serve as templates for the rehabilitation and recovery of other reaches of this and adjoining stream systems.

Macroinvertebrates

Environmental Objectives for Macroinvertebrates
Maintain or improve macroinvertebrate communities at or to SEPP (Waters of Victoria) objectives for AUSRIVAS, SIGNAL, minimum number of families and number of key families in the Cleared Hills and Coastal Plains segment.

Maintaining or improving the macroinvertebrate community to meet SEPP objectives requires the maintenance of a suitable low flow in reaches at all times. The baseflow should be sufficient to inundate the major habitats for macroinvertebrate production. In the Gellibrand River and tributaries covered by this study, the main bed materials in the shallow riffle/run habitats are sand, silt or clay, which generally supports a lower (but distinct) macroinvertebrate community. The baseflow requirements for this type of habitat is mainly to keep the bed damp, so a minimal depth of flowing water would be required.

However, important habitats in these sand-bed streams are accumulations of leaves that form on the stream bed. These can support a diverse assemblage of macroinvertebrates, and need to be inundated throughout the year. Although the size of leaf packs can vary, a suitable hydraulic surrogate to maintain these habitats is to provide flowing water up to 10 cm deep over the majority of the bed.

Edge habitats along the banks are used in the evaluation of SEPP objectives, and require an adequate baseflow to maintain inundation of fringing vegetation – a flowing water width in riffle/run habitats that extends from bank-toe to bank-toe. This would also ensure the lower portions of any woody debris in these areas are inundated (wood debris is another important macroinvertebrate habitat in sand/silt/clay bed streams).

In pool habitats, a baseflow requirement is less important as the hydraulic controls for pools would ensure that they are full (with edges inundated), even at cease to flows.

Additional to adequate low flows, short periods of higher flows (low flow freshes) are required to prevent the build up of fine sediment on the bed of riffle habitats at times of year when flows are low. These low flow freshes also help to arrest the decline in pool water quality over the warmer months.

Higher scouring flows are required to disturb the algae/bacteria/organic biofilm present on rocks or woody debris (a major food source for macroinvertebrates). This disturbance is believed to maintain a diversity of available food sources.

In reaches with adequate riparian vegetation, the major basis of the in-stream food chain is derived from organic material from outside of the stream channel. Dissolved organics, leaves and twigs that are washed from vegetated benches in the channel and from the floodplain are therefore essential to maintain macroinvertebrate communities. These leaves also form the basis of leaf packs in the stream. Higher flows that inundate benches and overbank flows that wash organic material into the stream are a further important component of any flow regime for macroinvertebrates.

While platypus are not directly included as an individual objective, general objectives set for the macroinvertebrates in the system have been set with consideration for platypus' food source, habitat availability and abundance in the Gellibrand River system. It is in this regard that platypus are considered an important environmental asset of the Gellibrand system.

Fish

Environmental Objectives for Native Fish
Maintain or restore self-sustaining populations of River Blackfish
Maintain or restore self-sustaining populations of Australian Grayling
Maintain or restore self-sustaining populations of small non-migratory species.
Maintain or restore self-sustaining populations of larger non-migratory species.
Maintain or restore self-sustaining populations of migratory species.
Maintain or restore self-sustaining populations of wetland species.

A major issue with regards to the provision of water for all groups of native fish is to ensure that refuge habitats in deeper pools remain to maintain populations during low flow periods (water depths with a minimum or median depth of 20 cm have previously been used as a hydraulic surrogate for small fish, and 40 cm for larger fish, including River Blackfish and Australian Grayling). However, acknowledging the special importance of the River Blackfish populations in the Gellibrand River, a deeper hydraulic surrogate median depth of 50 cm is recommended for this species. This follows the case in the Little Yarra River FLOWS study, where the local significance of the population was used to implement a more conservative hydraulic surrogate.

Similar to pool macroinvertebrate fauna, freshes during the spring/summer period are required to maintain or improve water quality within the pool habitats.

For non-migratory species, it is necessary to preserve flows that allow for the redistribution of populations following low flow periods. The natural rise in water level, particularly during Transitional Low to High Flow period is important to allow the movement of individuals, thus mixing the populations and allowing fish to recolonise vacant habitats. Suitable flows for this can be derived from the depth of water over critical shallow areas in the reach, allowing fish passage. Hydraulic criteria for establishing these flows can be allowing 12 cm depth for smaller fish and 20 cm depth for larger species.

In southern Victorian streams, the main spawning period for non-migratory fish species found in the Gellibrand River is between Spring and Summer (Koehn and O'Connor, 1990). Most smaller non-migratory species lay eggs either on the riverbed substrate or on vegetation, so regular flushes of water are required in the lead up to the breeding season to prevent excessive sedimentation of spawning substrates. River Blackfish lay eggs in hollow logs or between boulders. Although the adults guard and fan the eggs to prevent sedimentation, freshes during spring and summer are important for maintaining adequate water quality for larval, juvenile and adult survival, and to prevent sedimentation of larval and juvenile habitats.

Many migratory species require rises in flows during the breeding season to initiate spawning and migration. Flows that provide a spawning cue and adequate depths for migration of spawning adult fish are required during the autumn spawning/migration period (corresponding to the Transitional and early High Flow periods). There are no data that allow the precise determination of the flows required to stimulate spawning or migration in these species.

For wetland species, the main flow requirements would be the regular inundation of wetland habitats through bankfull flows (which would inundate local wetlands connected to the river by feeder channels) and overbank flows which would connect wetlands more distant from the channel.

Vegetation

Environmental Objectives For Vegetation
Stimulate the natural requirements of native vegetation to assist with reproduction, regeneration and seed dispersal and provide suitable site conditions for EVC's.

Maintaining or improving the quality of instream and riparian vegetation requires an integrated approach of on-ground management practices in conjunction with the vegetation's flow requirements. Instream vegetation within this catchment is best supported by constant low flows although some vegetation will tolerate temporary drying. Generally, the base flow should be sufficient to inundate the major habitats for instream vegetation. Pool habitats will not necessarily require constant flow because vegetation will be inundated with varied flow throughout other periods. Low flows will support the requirement of a variety of instream vegetation.

Instream vegetation can also become over abundant if high flows are reduced. High flows and the resultant scouring of the bed, bars and lower benches play an important role in controlling growth of these plants. Any reduction in the frequency or duration of peak flows may result in increased plant growth in the watercourse.

During periods of low flow (generally summer), short periods of higher flows (low flow freshes) are required to prevent sedimentation and maintain channel form, and to redistribute seeds and propagules.

High flow is necessary in winter and spring to enable wetting of the banks and floodplain. Higher flows that inundate benches are required for vegetation establishment and overbank flows are an important component of the flow regime to enable the establishment of seedlings. Overbank flow is not relevant to gorge country however high flows are important in maintaining riparian EVC extent and preventing terrestrial EVC encroachment.

The Riparian Forest EVC dominates the main stem of the Gellibrand River and its major tributaries. Although not reliant on episodic events like flood for species recruitment, it is described in the EVC benchmarks as ‘regularly inundated and permanently moist’. Regular inundation is therefore assumed part of the natural flow regime of the Gellibrand River riparian zone and without the zone being ‘permanently moist’ it is expected that the original riparian extent will deteriorate in health and potentially narrow in width.

4 Reach Condition and Environmental Objectives

Environmental, flow dependent objectives for the Gellibrand River catchment are proposed in the following section. These objectives have been developed following a literature review, Technical Panel assessment of a representative site within each reach and a meeting with the Advisory Group to identify assets and values in the reaches. Conditions observed at the representative site during the Technical Panel assessment form the basis for development of objectives however, where appropriate, reference is also made to conditions found more generally throughout the reach.

Estuarine processes of the lower reach of the Gellibrand River are discussed in this section, however as this does not form a component of the FLOWS methodology, flow objectives for the reach are not set.

Reach One – Love Creek Catchment

Reach 1 encompasses the Love Creek catchment, which includes tributaries such as Yahoo Creek, Ten Mile Creek and Porcupine Creek. Love Creek is a major tributary to the upper reaches of the Gellibrand River. The creek is surrounded by predominantly rural landuses with some remnant wet sclerophyll forest.

Reach Vision

To maintain existing physical form and processes and the diversity of aquatic and riparian species.

Hydrology

Current average annual streamflow in this reach has reduced from natural (undeveloped) conditions by 260 ML (approximately 2.2%), of which 204 ML[1] may be attributed to farm dams located within the catchment. Estimated rural demands account for a further 253 ML[2], the majority of which is required for winterfill and irrigation.

The greatest reductions are evident in the low flow months of January through to May, with a reduction in the 50th percentile summer flow from 4 ML/day under natural (undeveloped) conditions to 3 ML/day under current conditions. Higher flows are not considerably impacted, most likely due to the fact that small storages, such as farm dams, collect base flow and then overtop during larger rain events.

This sub-catchment is effectively fully developed with regard to water demands.

[1] GHD (2005) *Gellibrand REALM Development: Model Setup and Calibration Report*. Prepared for Corangamite CMA, December 2005

[2] *Ibid* (2005)

Physical Form

The representative reach of Love Creek comprises an intact, upland, partly confined, stream system with alternating floodplain pockets.

The stream bed is of a pool and riffle form with the bed material comprised of silts to gravel. Large wood provides additional substrate material and diversity. The bank material is comprised of clays, silts and sands with intact vegetative protection and isolated bedrock controls.

There is no evidence of excess sediment supply nor of post settlement alluvium (PSA) within the floodplain pockets.

Aquatic Ecology and Water Quality

The main macroinvertebrate habitats are in the pools, the sand bed of connecting shallow runs, leaf packs, edge vegetation and woody debris. Water quality over extended dry periods will be a concern as pool volume declines, water temperature increases and dissolved oxygen declines.

The main fish species of significance present is River Blackfish. There are other small-bodied fish present, both migratory (Common galaxias) and resident. Freshwater crayfish have also been identified in this reach.

Vegetation

A remnant patch of EVC 18 Riparian Forest (Otway Plain Bioregion) exists at this site. The vegetation is dominated by a Manna Gum canopy with Blackwoods abundant in the sub canopy. Species diversity is high and the forest has relatively low weed presence. There is an abundance of large and small shrubs and the ground layer also contained a variety of herbs, grasses and ferns. Ferns are relatively abundant on both banks. The forest appeared healthy and the abundance of sword-sedge offstream suggested some areas remained relatively wet.

The car park area is more disturbed and many weed species are present in the vicinity including Crack Willow, Ivy and broad leaf weeds. Blackberry is also abundant particularly on the opposite (right) bank. Bracken was observed colonising a higher bank bench, perhaps indicating a recent lack of wetting frequency and duration.

Summary of Condition for Reach One

The representative site of Love Creek is in moderate to good condition. Two sites on Love Creek have been included in the recent Index of Stream Condition (ISC) assessments. Physical form at the site is generally good. Hydrology is modified from natural catchment conditions with most of the change occurring during the autumn period. Seasonality of flows remain the same as natural conditions.

Flow Objectives for Reach One

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
Macroinvertebrates	Maintain self sustaining populations of macroinvertebrates	1-M1	Habitat availability (inundation of leaf packs and shallow runs from edge to edge)	Low flow	All year
		1-M2	Water quality maintenance	Low flow	Low flow season
		1-M3	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		1-M4	Flush habitat	High flow fresh	High flow season
		1-M5	Entrain terrestrial carbon	Overbank	High flow season
Fish	Maintain self sustaining populations of River Blackfish and small-bodied fish	1-F1	Habitat availability for River Blackfish	Low flow	All year
		1-F2	Habitat availability for small-bodied fish	Low flow	All year
		1-F3	Localised movement of small-bodied fish	Low flow fresh	Early low flow season
		1-F4	Localised movement of small-bodied fish	High flow	Late high flow season
		1-F5	Migration movement of small-bodied migratory fish	High flow	Early high flow season
		1-F6	Migration stimulation of small-bodied migratory fish	High flow fresh	Early high flow season
		1-F7	Spawning stimulation of small-bodied resident fish	High flow fresh	Late high flow season
		1-F8	Water quality maintenance	Low flow	Low flow season
		1-F9	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		1-F10	Flush habitat	High flow fresh	High flow season
Water Quality	Maintain water quality to meet environmental objectives	1-W1	Flushing of pools	Low flow fresh	Summer
Physical Form	Provide suitable conditions to maintain and protect channel morphology and dependant assets and processes	1-P1	Maintain frequency and duration of mid bank to overbank flows to within 20% of natural	High flow freshes & overbank	Any time
		1-P2	No change in the occurrence and timing of events that maintain scour holes. Bed disturbance minimum average flow of 0.3 m/s through pool in sand bed	Low flow freshes	Any time
		1-P3	Provide natural frequency of overbank flows to maintain sediment accession onto the floodplain	Overbank	Any time

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
		1-P4	Refer vegetation criteria	Freshes	Any time
		1-P5	Bench formation/ provision of flow over benches	High flow fresh	Any time
		1-P6	Bank and bed scour processes	Bankfull	Any time
Vegetation	Maintain/restore distinctive riparian vegetation community and structure including zonation up the bank, and discouraging exotic species	1-V1	Habitat inundation – provision of moisture to benches	High flow fresh	Winter/Spring
		1-V2	Habitat inundation – provision of moisture to floodplain	Overbank	Winter/Spring
		1-V3	Habitat inundation – variability to provide zonation	High flow variability (high flow freshes, bankfull)	Any time (with natural rate of rise and fall)
		1-V4	Habitat regeneration – deposition of sediments on benches	High flow fresh	Any time
		1-V5	Habitat disturbance – bank/bench inundation to provide regeneration niches	High flow	Spring/Summer
		1-V6	Delivery of seeds from upper catchment	High flow	Any time
		1-V7	Prolonged inundation of bank and benches to disadvantage terrestrial species	Bankfull	Winter/Spring
		1-V8	Prevent over colonisation of instream vegetation	High flow fresh	Any time
		1-V9	Prolonged inundation of bars to disadvantage terrestrial species	High flow	Continuous over Winter
		1-V10	Maintain frequency and duration of mid bank to overbank flows to within 20% of natural	High flow freshes & overbank	Any time
		1-V11	Ensure near natural rates of overbank and high flows to within 20% of natural	High flows to overbank	Any time
		1-V12	Riparian disturbance	Overbank	Any time

Reach 2A – Gellibrand River at James Access Bridge

Reach Two covers the headwaters of the Gellibrand River, rising on the northern face of the Otway Ranges, through the mid-reaches of the Gellibrand, to the confluence with Carlisle River. This reach is divided into two, namely Reach 2A (discussed below), which extends from the Upper Gellibrand Reservoir through to the township of Gellibrand, and Reach 2B, which covers the remainder of the downstream reach.

Reach 2A includes the upper Gellibrand tributaries of Barramunga Creek, Olangolah Creek, Asplin Creek, Lardner Creek and Charleys Creek. Surrounding land use varies from undisturbed wet sclerophyll forest and cool temperate rainforest in the upper reaches, with some cleared grazing land and floodplain pockets downstream of the representative site at James Access Bridge. There are also conifer plantations in parts of the catchment.

Reach Vision

To maintain existing physical form and processes and the diversity of aquatic species. To restore and maintain the reach as an ecological corridor to downstream reaches.

Hydrology

Current average annual streamflow in this reach has reduced from natural (undeveloped) conditions by 3950 ML (approximately 8.5%), which is due primarily to the storage dams in the upper catchment.

Flow reduction is evident in all months of the year, however is most significant in the low flow summer and autumn months. The greatest reductions are evident in the low flow months of December through to May, with a reduction in 50^{th} percentile summer flow from 30 ML/day under natural conditions to 16 ML/day under current conditions.

Physical Form

The representative site for Reach 2A is an unconfined to partly confined reach of the Gellibrand River. Bank materials consist primarily of sandy clays. The river channel form through the representative reach is highly incised. Hydrologic and hydraulic analysis reveals the channel to contain flows up to the 50 year ARI event. This form appears natural with no evidence of contemporary incision. A small bench is evident in the cross section at the water surface elevation of the 2 year ARI event.

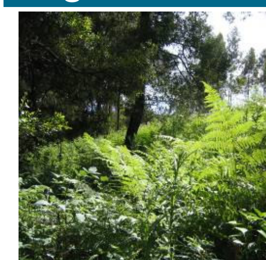
Disturbance of the bed is likely in summer fresh events. Retention of frequency and duration of flow events between 50% of the 2 year event up to the 5 year event (i.e. channel forming flow range) is important for the maintenance of gross channel form. Winter freshes with higher velocities are required to create some undercutting of the banks and maintain scour holes. Deposition onto the benches is evident and should be maintained. Low flow freshes are required for channel disturbance.

Aquatic Ecology and Water Quality

There are three or four major habitat types present at the representative site for Reach 2A. The larger deeper pools are home to populations of River Blackfish, while shallower run/pool with localised deeper areas provide habitat which supports small-bodied fish species. Long shallow sand bed runs with accumulated leaf packs should be kept inundated to maintain habitat for macroinvertebrates and small fish species.

Large woody debris provides stable habitat during higher flow periods and should therefore be maintained. Low flow periods result in silt build up on woody debris, and summer freshes are required to move silt, bacteria and algae growing on the wood. Scouring of the wood during high winter flows is important in maintaining a diversity of algae growth rather than domination by a single species. High-mid channel flows are required once to twice per year for carbon cycling, to provide lateral connection with the floodplain and to ensure organic debris is introduced into the stream.

Vegetation



The vegetation at this site shows likeness to EVC 18 in tree structure (e.g. Manna gums and Blackwood), but is characterised by an exotic understorey. Austral bracken is also dominate in the understorey and small shrubs are generally lacking. There has been some willow removal works downstream of the James Access bridge.

Seed dropping should be encouraged to assist in rehabilitation. Higher flows will assist with weed suppression, and winter floods will ensure saturation of the ground to prepared for natural seed drop.

Summary of Condition for Reach 2A

The representative site of the Gellibrand River is in good condition. Three sites on the upper part of the Gellibrand River have been included in the recent Index of Stream Condition (ISC) assessments and in Reach 2A aquatic life and water quality rate high in the ISC condition assessment. Hydrology is highly modified from natural catchment conditions with most of the change primarily due to the impact of the main dam in the upper catchment. Seasonality of flows remains the same as natural conditions.

Flow Objectives for Reach 2A

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
Macroinvertebrates	Maintain self sustaining populations of macroinvertebrates	2A-M1	Habitat availability (inundation of leaf packs and shallow runs from edge to edge)	Low flow	All year
		2A-M2	Water quality maintenance	Low flow	Low flow season
		2A-M3	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		2A-M4	Flush habitat	High flow fresh	High flow season
		2A-M5	Entrain terrestrial carbon	Overbank	High flow season
Fish	Maintain self sustaining populations of River Blackfish, Australian Grayling and small-bodied fish	2A-F1	Habitat availability for River Blackfish	Low flow	All year
		2A-F2	Habitat availability for Australian Grayling	Low flow	All year
		2A-F3	Habitat availability for small-bodied fish	Low flow	All year
		2A-F4	Localised movement of Australian Grayling and River Blackfish	Low flow fresh	Low flow season
		2A-F5	Spawning trigger / larval transport of Australian Grayling	Low flow fresh	April – May
		2A-F6	Localised movement of small-bodied fish	High flow	Late high flow season
		2A-F7	Migration movement of small-bodied migratory fish	High flow	Early high flow season
		2A-F8	Migration stimulation of small-bodied migratory fish	High flow fresh	Early high flow season
		2A-F9	Spawning stimulation of small-bodied resident fish	High flow fresh	Late high flow season
		2A-F10	Water quality maintenance	Low flow	Low flow season
		2A-F11	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		2A-F12	Flush habitat	High flow fresh	High flow season
Water Quality	Maintain water quality to meet environmental objectives	2A-W1	Flushing of pools	Low flow fresh	Summer
Physical Form	Provide suitable conditions to maintain and protect channel morphology and dependant assets and processes	2A-P1	Maintain frequency and duration of mid bank to overbank flows to within 20% of natural	High flow freshes & overbank	Anytime
		2A-P2	No change in the occurrence and timing of events that create scour holes	Low Flow Freshes	Anytime

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
		2A-P3	Provide natural frequency of overbank flows to maintain sediment accession onto the floodplain	Overbank	Anytime
		2A-P4	Refer vegetation criteria	Freshes	Anytime
		2A-P5	Bench formation/ provision of flow over benches	High flow fresh	Any time
		2A-P6	Bank scour process	Bankfull	Any time
Vegetation	Maintain/restore distinctive riparian vegetation community and structure including zonation up the bank, and discouraging exotic species	2A-V1	Habitat inundation – provision of moisture to benches	High flow fresh	Winter/Spring
		2A-V2	Habitat inundation – provision of moisture to floodplain	Overbank	Winter/Spring
		2A-V3	Habitat inundation – variability to provide zonation	High flow variability (high flow freshes, bankfull)	Any time (with natural rate of rise and fall)
		2A-V4	Habitat regeneration – deposition of sediments on benches	High flow fresh	Any time
		2A-V5	Habitat disturbance – bank/bench inundation to provide regeneration niches	High flow	Spring/Summer
		2A-V6	Delivery of seeds from upper catchment	High flow	Any time
		2A-V7	Prolonged inundation of bank and benches to disadvantage terrestrial species	Bankfull	Winter/Spring
		2A-V8	Prevent over colonisation of instream vegetation	High flow fresh	Anytime
		2A-V9	Prolonged inundation of bars to disadvantage terrestrial species	High flow	Continuous over Winter

Reach 2B – Upper Gellibrand River (downstream of 2A)

Reach 2B includes the mid-reach Gellibrand tributaries of Gum Gully Creek and Boggy Creek. Surrounding land use varies from modified wet sclerophyll forest in the upper reach, to cleared grazing land downstream of Bunkers Hill.

Reach Vision

To maintain existing physical form and processes and the diversity of aquatic species. To restore and maintain the reach as an ecological corridor between the estuary and the upland streams of the Otway Forests.

Hydrology

Current average annual streamflow in this reach has reduced from natural (undeveloped) conditions by 4230 ML (approximately 3.8%), which is due primarily to urban demand from the township of Colac (annual average demand 3735 ML[3]). There is also a reduction in streamflow due to farm dams storages, which have an estimated annual impact of 325 ML[4].

The greatest reductions are evident in the low flow months of December through to May, with a reduction in 50th percentile summer flow from 69 ML/day under natural conditions to 53 ML/day under current conditions. The higher flows are not significantly impacted under the current flow regime.

Physical Form

The representative site for Reach 2B comprises a floodplain pocket within a confined and partly confined reach of the Gellibrand River. The floodplain pocket has been cleared for agriculture.

The river comprises a pool and run sequence through the longitudinal profile. The stream bed is comprised of sand, with the shallow run sections armoured to a limited extent by water ribbon and large wood. Deep pools are present, these also contain significant volumes of large wood.

The banks are steep and contain clays, silts and sands with dense native and introduced exotic invasive species. Isolated bedrock controls are present in the bank.

Isolated depositional benches are present within the channel.

A billabong is present on the floodplain pocket. However this has been isolated from regular inundation through the construction of a levee bank.

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[3] GHD (2005) *Gellibrand REALM Development: Model Setup and Calibration Report*. Prepared for Corangamite CMA, December 2005

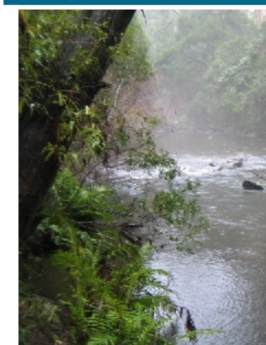
[4] *Ibid* (2005)

Aquatic Ecology and Water Quality

The main macroinvertebrate habitats are in the pools, the sand bed of connecting shallow runs, leaf packs, edge vegetation and woody debris. Water quality over extended low flow periods will be a key concern, particularly where direct stock access to the waterway is possible.

The main fish species of significance present are River Blackfish and Australian Grayling. There are also other small-bodied fish present, both migratory and resident.

Vegetation



The vegetation at this site is modified EVC 18 Riparian Forest (edge of the Otway Plain & Otway Ranges Bioregion). The site is located adjacent to cleared 'improved' pasture. Large offstream billabongs are present within the adjacent floodplain and, despite being grazed, contained native instream and fringing vegetation. Blackberries dominate the banks on both sides of the river. Manna Gums, Blackwoods, Olearia, Pomaderris and Prostanthera are the dominant native woody species present. Sedges are present on the lower banks however cattle are grazing/disturbing vegetation on the sandy bars. Stock pressures and blackberries are limiting vegetation re-establishment. Bracken is present.

Summary of Condition for Reach 2B

The representative site of the Gellibrand River is in moderate condition. Three sites on the upper part of the Gellibrand River have been included in the recent Index of Stream Condition (ISC) assessments and in Reach 2B aquatic life rates high in the ISC condition assessment. The creek displays a variety of features including a billabong present on the left bank and aquatic life rates high in the ISC condition assessment. Hydrology is modified from natural catchment conditions with most of the change occurring during the autumn period. Seasonality of flows remain the same as natural conditions.

Flow Objectives for Reach 2B

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
Macroinvertebrates	Maintain self sustaining populations of macroinvertebrates	2B-M1	Habitat availability (inundation of leaf packs and shallow runs from edge to edge)	Low flow	All year
		2B-M2	Water quality maintenance	Low flow	Low flow season
		2B-M3	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		2B-M4	Flush habitat	High flow fresh	High flow season
		2B-M5	Entrain terrestrial carbon	Overbank	High flow season
Fish	Maintain self sustaining populations of River Blackfish, Australian Grayling and small-bodied fish	2B-F1	Habitat availability for River Blackfish	Low flow	All year
		2B-F2	Habitat availability for Australian Grayling	Low flow	All year
		2B-F3	Habitat availability for small-bodied fish	Low flow	All year
		2B-F4	Localised movement of Australian Grayling and River Blackfish	Low flow fresh	Low flow season
		2B-F5	Spawning trigger / larval transport of Australian Grayling	Low flow fresh	April – May
		2B-F6	Localised movement of small-bodied fish	High flow	Late high flow season
		2B-F7	Migration movement of small-bodied migratory fish	High flow	Early high flow season
		2B-F8	Migration stimulation of small-bodied migratory fish	High flow fresh	Early high flow season
		2B-F9	Spawning stimulation of small-bodied resident fish	High flow fresh	Late high flow season
		2B-F10	Water quality maintenance	Low flow	Low flow season
		2B-F11	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		2B-F12	Flush habitat	High flow fresh	High flow season
Water Quality	Maintain water quality to meet environmental objectives	2B-W1	Flushing of pools	Low flow fresh	Summer
Physical Form	Provide suitable conditions to maintain and protect channel morphology and dependant assets and processes	2B-P1	Maintain frequency and duration of mid bank to overbank flows to within 20% of natural	High flow freshes & overbank	Anytime
		2B-P2	No change in the occurrence and timing of events that create scour holes	Low Flows Freshes	Anytime

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
		2B-P3	Provide natural frequency of overbank flows to maintain sediment accession onto the floodplain	Overbank	Anytime
		2B-P4	Refer vegetation criteria	Freshes	Anytime
		2B-P5	Bench formation/ provision of flow over benches	High flow fresh	Any time
		2B-P6	Bank scour process	Bankfull	Any time
Vegetation	Maintain/restore distinctive riparian vegetation community and structure including zonation up the bank, and discouraging exotic species	2B-V1	Habitat inundation – provision of moisture to benches	High flow fresh	Winter/Spring
		2B-V2	Habitat inundation – provision of moisture to floodplain	Overbank	Winter/Spring
		2B-V3	Habitat inundation – variability to provide zonation	High flow variability (high flow freshes, bankfull)	Any time (with natural rate of rise and fall)
		2B-V4	Habitat regeneration – deposition of sediments on benches	High flow fresh	Any time
		2B-V5	Habitat disturbance – bank/bench inundation to provide regeneration niches	High flow	Spring/Summer
		2B-V6	Delivery of seeds from upper catchment	High flow	Any time
		2B-V7	Prolonged inundation of bank and benches to disadvantage terrestrial species	Bankfull	Winter/Spring
		2B-V8	Prevent over colonisation of instream vegetation	High flow fresh	Anytime
		2B-V9	Prolonged inundation of bars to disadvantage terrestrial species	High flow	Continuous over Winter

Reach Three – Carlisle River Catchment

Reach 3 encompasses the Carlisle River and its tributaries Cole Creek, Camp Creek and Arkins Creek. Carlisle River is a major tributary to the Gellibrand River and enters the Gellibrand River at the township of Carlisle River. The upper tributaries flow through wet sclerophyll forest and cool temperate rainforest. Approaching the confluence with the Gellibrand River, the land has been cleared for agriculture and plantations.

Reach Vision

Provide flows that support the restoration of self-sustaining populations of aquatic and riparian species and ecosystem processes in accordance with Resource Condition Targets in the CCMA River Health Strategy.

Hydrology

Current average annual streamflow in this reach has reduced from natural (undeveloped) conditions by 3220 ML (approximately 7.9%). This is primarily due to the Otway Main Pipeline, which extracts up to 15 ML/day[5] from the upper reaches of Arkins Creek. Rural demand (mainly for irrigation purposes) reduces annual streamflow by an additional 601 ML[6], plus an estimated 43 ML[7] due to farm dam storages.

Flow reduction is evident in all months of the year, however is most significant in the low flow summer and autumn months. The 50th percentile summer flows is reduced from 43 ML/day under natural conditions to 38 ML/day under current conditions. Higher winter flows are also impacted, with 50th percentile flows reduced from 157 ML/day to 143 ML/day.

Physical Form

The representative site for Reach 3 comprises an unconfined, alluvial, continuous, single channel, meandering stream. The stream comprises a pool and riffle stream bed longitudinal profile, reflecting the meander sequence, with pools being typically present adjacent to the outside of meander bends.

The stream bed and banks are comprised of clays and fine silts. Large wood was not a feature of the stream system. The stream banks had been cleared of vegetation (willow management) and were exposed to ongoing fluvial processes. A revegetation program has been undertaken to limit ongoing channel adjustments. Consistent with the unconfined stream type there is no bedrock evident in the bed or banks.

Depositional inchannel benches are present on the inside of meander bends. The floodplain has been cleared of vegetation.

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[5] GHD (2005) *Gellibrand REALM Development: Model Setup and Calibration Report*. Prepared for Corangamite CMA, December 2005

[6] *Ibid* (2005)

[7] *Ibid* (2005)

Aquatic Ecology and Water Quality

The main macroinvertebrate habitats in the reach are in the pools, the sand bed of connecting shallow runs, leaf packs, edge vegetation and woody debris. Water quality over extended dry periods will be a key concern.

The main fish species of significance present are River Blackfish and Australian Grayling. There are other small-bodied fish present, both migratory and resident. Freshwater crayfish have also been identified in this reach.

Vegetation

The vegetation at this site was originally EVC 18 Riparian Forest (Otway Plain Bioregion) which has now been almost totally cleared. The floodplain and riparian zone has been cleared for agriculture and very few remnants remain. There is therefore little remnant native vegetation to protect however revegetation works have occurred and near natural flow regimes will allow/assist suitable re-establishment. Blackwoods are present offstream surrounding a palaeo channel, however they are possibly surviving on localised runoff and not overbank flows. Weeds are abundant at this site with the more invasive species including Cape Ivy, Japanese Honeysuckle, Tradescantia, Blackberry, 3 Cornered Garlic and White Poplars. These and other broadleaf weeds may be suppressed by prolonged inundation however overbank flows may also distribute weed seed and propagules downstream. Instream, bar and bench vegetation will naturally establish with suitable wetting regimes.

Summary of Condition for Reach Three

The representative site of Carlisle River is currently undergoing rehabilitation works in the form or a revegetation program. Recent ISC assessments indicate the condition of Carlisle River overall is good. One site on the river has been included in the recent Index of Stream Condition assessments. Moderate habitat features such as large woody debris are evident in the reach and aquatic life was evident during site inspections however the presence of willows has altered channel form. Hydrology is modified from natural catchment conditions with most of the change occurring during the autumn period. Seasonality of flows remain the same as natural conditions.

Flow Objectives for Reach Three

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
Macroinvertebrates	Maintain self sustaining populations of macroinvertebrates	3-M1	Habitat availability (inundation of leaf packs and shallow runs from edge to edge)	Low flow	All year
		3-M2	Water quality maintenance	Low flow	Low flow season
		3-M3	Refresh water quality and flush	Low flow fresh	Low flow season
		3-M4	Flush habitat	High flow fresh	High flow season
		3-M5	Entrain terrestrial carbon	High flow fresh and overbank	High flow season / June-Oct
Fish	Maintain self sustaining populations of River Blackfish, Australian Grayling and small-bodied fish	3-F1	Habitat availability for River Blackfish	Low flow	All year
		3-F2	Habitat availability for Australian Grayling	Low flow	All year
		3-F3	Habitat availability for small-bodied fish	Low flow	All year
		3-F4	Localised movement of Australian Grayling and River Blackfish	Low flow fresh	Low flow season
		3-F5	Spawning trigger / larval transport of Australian Grayling	Low flow fresh	April – May
		3-F6	Localised movement of small-bodied fish	High flow	Late high flow season
		3-F7	Migration movement of small-bodied migratory fish	High flow	Early high flow season
		3-F8	Migration stimulation of small-bodied migratory fish	High flow fresh	Early high flow season
		3-F9	Spawning stimulation of small-bodied resident fish	High flow fresh	Late high flow season
		3-F10	Water quality maintenance	Low flow	Low flow season
		3-F11	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		3-F12	Flush habitat	High flow fresh	High flow season
Water Quality	Maintain water quality to meet environmental objectives	3-W1	Flushing of pools	Low flow fresh	Summer
Physical Form	Provide suitable conditions to maintain and protect channel morphology and dependant assets and processes	3-P1	Maintain frequency and duration of mid bank to overbank flows to within 20% of natural	High flow freshes & overbank	Any time
		3-P2	No change in the occurrence and timing of events that create scour holes	Low Flow Freshes	Any time

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
		3-P3	Provide natural frequency of overbank flows to maintain sediment accession onto the floodplain	Overbank	Any time
		3-P4	Refer vegetation criteria	Freshes	Any time
		3-P5	Bench formation/ provision of flow over benches	High flow fresh	Any time
		3-P6	Bank scour process	Bankfull	Any time
Vegetation	Maintain/restore distinctive riparian vegetation community and structure including zonation up the bank, and discouraging exotic species	3-V1	Habitat inundation – provision of moisture to benches	High flow fresh	Winter/Spring
		3-V2	Habitat inundation – provision of moisture to floodplain	Overbank	Winter/Spring
		3-V3	Habitat inundation – variability to provide zonation	High flow variability (high flow freshes, bankfull)	Any time (with natural rate of rise and fall)
		3-V4	Habitat regeneration – deposition of sediments on benches	High flow fresh	Any time
		3-V5	Habitat disturbance – bank/bench inundation to provide regeneration niches	High flow	Spring/Summer
		3-V6	Delivery of seeds from upper catchment	High flow	Any time
		3-V7	Prolonged inundation of bank and benches to disadvantage native terrestrial species	Bankfull	Winter/Spring
		3-V8	Prevent over colonisation of instream vegetation	High flow fresh	Anytime
		3-V9	Prolonged inundation of bank and benches to disadvantage terrestrial exotic species	Bankfull	Winter /Spring

Reach Four – Gellibrand River Mid Reach

The mid reach of the Gellibrand River encompasses the area from the confluence with Carlisle River (upstream of the Otway Main Pipeline pumping station) past the township of Burrupa and through to the Great Ocean Road (the commencement of the estuarine reach). This reach flows through areas dominated by rural landuses and is impacted by agricultural runoff and uncontrolled stock access. Tributaries through this reach include Leahy Creek, Sandy Creek, Chapple Creek, Jones Creek and Atkinson Creek.

Reach Vision

To maintain existing physical form and processes and the diversity of aquatic species. To restore and maintain the reach as an ecological corridor between the estuary and the upland streams of the Otway Forests.

Hydrology

Current average annual streamflow in this reach has reduced from natural (undeveloped) conditions by 15,900 ML (approximately 6%). Urban extractions at the South Otway Pipeline contributes the greatest impact to streamflow, with an average annual demand of 3746 ML[8]. To supplement extractions for the North Otway Supply System from Arkins Creek (Reach 3), water is also diverted from this reach of the Gellibrand near the confluence with Leahy Creek. Farm dams storages result in a further impact in the order of 70 ML[9], plus rural demand in the order of 370 ML[10].

The greatest reductions are evident in the low flow months of December through to May, with a reduction in 50th percentile summer flow from 168 ML/day under natural conditions to 118 ML/day under current conditions. The higher flows are not significantly impacted under the current flow regime.

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[8] GHD (2005) *Gellibrand REALM Development: Model Setup and Calibration Report*. Prepared for Corangamite CMA, December 2005

[9] *Ibid* (2005)

[10] *Ibid* (2005)

Physical Form

The representative site for this reach of river comprises an alluvial, unconfined, meandering, single channel continuous, stream system.

The stream bed comprises a pool and run sequence. Large wood was present through the system.

Consistent with the unconfined classification there are no bedrock controls on the stream within the representative site. The pool and run depth prevented identification of the bed sediment. Recent bank slumping was noted and is indicative of slumps throughout the reach. Inchannel depositional bars and benches were present. These benches were comprised of silts and sands. Some protective vegetation was present. However the reach is subject to uncontrolled grazing pressure.

The floodplain included a small inset terrace. The floodplain and terrace were cleared of vegetation.

Aquatic Ecology and Water Quality

The main macroinvertebrate habitats in the reach are in the pools, the sand bed of connecting shallow runs, leaf packs, edge vegetation and woody debris. Water quality over extended dry periods will be a key concern.

The main fish species of significance present are River Blackfish and Australian Grayling. There are other small-bodied fish present, both migratory and resident.

Vegetation

The vegetation at this site is modified EVC 18 Riparian Forest (Warrnambool Plain Bioregion). The floodplain and riparian zone has been substantially cleared for agriculture. The river banks are dominated by Blackwoods with the occasional gum also present. Pasture grasses and broadleaf weeds dominate the ground layer, particularly above bank on the floodplain. Some Juncus and Lomandra are present above bank however dairy cow grazing and pasture improvement has left the floodplain virtually devoid of native ground cover. Billabong depressions contain some native species including Juncus and Persicaria. Some native shrub species are present on the banks including Hymenanthera, Coprosma, and Cassinia. The occasional Poa and patches of Bidgee-widgee were also observed on banks. Pussy Willow is scattered throughout the assessment site as are patches of Tradescantia. The exotic pasture grass, Cocksfoot, dominates the bank's ground layer at this site.

Summary of Condition for Reach Four

The representative site of the lower reach of the Gellibrand River is in moderate condition. Hydrology is modified with increased periods of low flow however seasonality of flows remain the same as natural conditions. Physical form is generally good however fish migration barriers are present beyond the site on the Gellibrand River Road. Water quality is defined through the ISC results as being good with some elevated levels of total phosphorous.

Flow Objectives for Reach Four

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
Macroinvertebrates	Maintain self sustaining populations of macroinvertebrates	4-M1	Habitat availability (inundation of leaf packs and shallow runs from edge to edge)	Low flow	All year
		4-M2	Water quality maintenance	Low flow	Low flow season
		4-M3	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		4-M4	Flush habitat	High flow fresh	High flow season
		4-M5	Entrain terrestrial carbon	High flow fresh and overbank	High flow season / June-Oct
Fish	Maintain self sustaining populations of River Blackfish, Australian Grayling and small-bodied fish	4-F1	Habitat availability for River Blackfish	Low flow	All year
		4-F2	Habitat availability for Australian Grayling	Low flow	All year
		4-F3	Habitat availability for small-bodied fish	Low flow	All year
		4-F4	Localised movement of Australian Grayling and River Blackfish	Low flow fresh	Low flow season
		4-F5	Spawning trigger / larval transport of Australian Grayling	Low flow fresh	April – May
		4-F6	Localised movement of small-bodied fish	High flow	Late high flow season
		4-F7	Migration movement of small-bodied migratory fish	High flow	Early high flow season
		4-F8	Migration stimulation of small-bodied migratory fish	High flow fresh	Early high flow season
		4-F9	Spawning stimulation of small-bodied resident fish	High flow fresh	Late high flow season
		4-F10	Water quality maintenance	Low flow	Low flow season
		4-F11	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		4-F12	Flush habitat	High flow fresh	High flow season
Water Quality	Maintain water quality to meet environmental objectives	4-W1	Flushing of pools	Low flow fresh	Summer
Physical Form	Provide suitable conditions to maintain and protect channel morphology and dependant assets and processes	4-P1	Maintain frequency and duration of mid bank to overbank flows to within 20% of natural	High flow freshes & overbank	Anytime
		4-P2	No change in the occurrence and timing of events that create scour holes	Low Flow Freshes	Anytime

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
		4-P3	Provide natural frequency of overbank flows to maintain sediment accession onto the floodplain	Overbank	Anytime
		4-P4	Refer vegetation criteria	Freshes	Anytime
		4-P5	Bench formation/ provision of flow over benches	High flow fresh	Any time
		4-P6	Bank scour process	Bankfull	Any time
Vegetation	Maintain/restore distinctive riparian vegetation community and structure including zonation up the bank	4-V1	Habitat inundation – provision of moisture to benches	High flow fresh	Winter/Spring
		4-V2	Habitat inundation – provision of moisture to floodplain	Overbank	Winter/Spring
		4-V3	Habitat inundation – variability to provide zonation	High flow variability (high flow freshes, bankfull)	Any time (with natural rate of rise and fall)
		4-V4	Habitat regeneration – deposition of sediments on benches	High flow fresh	Any time
		4-V5	Habitat disturbance – bank/bench inundation to provide regeneration niches	High flow	Spring/Summer
		4-V6	Delivery of seeds from upper catchment	High flow	Any time
		4-V7	Prolonged inundation of bank and benches to disadvantage native terrestrial species	Bankfull	Winter/Spring
		4-V8	Prevent over colonisation of instream vegetation	High flow fresh	Anytime
	Maintain health of above bank vegetation	4-V9	Ensure near natural rates of overbank and high flows	High flows to bankfull	Anytime

Reach Five – Kennedys Creek Catchment

Kennedys Creek is the major western tributary to the Gellibrand River. The western side of the catchment has been largely cleared for agriculture and there is a high proportion of exotic vegetation. Kennedys Creek flows into the Gellibrand River at the South Otway Pipeline pumping station. Tributaries include Muree Creek, Tomahawk Creek and Danger Creek.

Reach Vision

To maintain the current aquatic diversity, physical form and ecosystem processes in Kennedys Creek, and provide a flow regime that supports the restoration of the riparian condition and ecologically healthy corridor.

Hydrology

Current average annual streamflow in this reach has reduced from natural (undeveloped) conditions by 1720 ML (approximately 4.2%). This is primarily attributed to the impact of farm dam storages, which reduce annual stream flow by 1683 ML[11]. Rural demand accounts for an additional streamflow reduction of 32 ML[12].

The greatest reductions are evident in the low flow months of December through to May, with a reduction in 50th percentile summer flow from 6 ML/day under natural conditions to 4 ML/day under current conditions. The magnitude of peak flow events during summer and autumn have also been reduced.

Physical Form

The representative site within Reach 5 comprises an unconfined, alluvial, single channel, continuous stream system. The stream has a pool riffle streambed profile. The stream bed comprises silts, sands and gravels. The stream bed is also colonised by aquatic reeds and grasses. The extent of vegetation colonisation in the system, particularly downstream of the subject site, hints that this system may be evolving toward an alternate stream form such as a chain of ponds. This also suggests that the current stream form may be the result of past drainage works.

The stream is characterised by recently fallen instream timber.

The floodplain has been cleared of vegetation for agricultural pursuits.

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[11] GHD (2005) *Gellibrand REALM Development: Model Setup and Calibration Report*. Prepared for Corangamite CMA, December 2005

[12] *Ibid* (2005)

Aquatic Ecology and Water Quality

The main macroinvertebrate habitats in the reach are in the pools, the sand bed of connecting shallow runs, leaf packs, edge and in-stream vegetation and woody debris. Water quality over extended dry periods will be a key concern.

The main fish species of significance present are River Blackfish. Australian Grayling is assumed not to have a sustainable population in the reach. There are other small-bodied fish present, both migratory (Common galaxias and Spotted galaxias) and resident (Southern pygmy perch).

Vegetation

The vegetation at this site is modified EVC 18 Riparian Forest (edge of the Otway Plain & Warrnambool Plain Bioregion). This site is grazed and the floodplain cleared with pugging evident near the waterway. There is little native vegetation offstream on the floodplain and a line of Manna Gums and Blackwood lines the waterway. The pasture grass, Cocksfoot, dominates the banks and instream bars. The native aquatic water ribbons were observed instream and other natives were also observed including Pomaderris, Coprosma, Juncus, Carex, Clematis and Ranunculus. Other weed species present adjacent to the waterway include Blackberry, Prunus sp., thistles and Cleavers.

Summary of Condition for Reach Five

The current flow regime of Kennedys Creek is characterised by a general decrease in flows particularly during the summer and autumn periods. Recent ISC assessments indicate the condition of Kennedys Creek overall is moderate. Two sites on the river have been included in the recent Index of Stream Condition assessments. No physical fish barriers were present and moderate habitat features such as large woody debris are evident in the reach. Quality of instream vegetation is good with much of the representative site dominated by reeds.

Flow Objectives for Reach Five

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
Macroinvertebrates	Maintain self sustaining populations of macroinvertebrates	5-M1	Habitat availability (inundation of leaf packs, in-stream vegetation and shallow runs from edge to edge)	Low flow	All year
		5-M2	Water quality maintenance	Low flow	Low flow season
		5-M3	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		5-M4	Flush habitat	High flow fresh	High flow season
		5-M5	Entrain terrestrial carbon	High flow fresh and overbank	High flow season / June-Oct
Fish	Maintain self sustaining populations of River Blackfish and small-bodied fish	5-F1	Habitat availability for River Blackfish	Low flow	All year
		5-F2	Habitat availability for small-bodied fish	Low flow	All year
		5-F3	Localised movement of small-bodied fish	Low flow fresh	Low flow season
		5-F4	Localised movement of small-bodied fish	High flow	Late high flow season
		5-F5	Migration movement of small-bodied migratory fish	High flow	Early high flow season
		5-F6	Migration stimulation of small-bodied migratory fish	High flow fresh	Early high flow season
		5-F7	Spawning stimulation of small-bodied resident fish	High flow fresh	Late high flow season
		5-F8	Water quality maintenance	Low flow	Low flow season
		5-F9	Refresh water quality and flush habitat	Low flow fresh	Low flow season
		5-F10	Flush habitat	High flow fresh	High flow season
Water Quality	Maintain water quality to meet environmental objectives	5-W1	Flushing of pools	Low flow fresh	Summer
Physical Form	Provide suitable conditions to maintain and protect channel morphology and dependant assets and processes	5-P1	Maintain frequency and duration of mid bank to overbank flows to within 20% of natural	High flow freshes & overbank	Any time
		5-P2	No change in the occurrence and timing of events that create scour holes	Low Flow Freshes	Any time
		5-P3	Provide natural frequency of overbank flows to maintain sediment accession onto the floodplain	Overbank	Any time

Asset	Environmental Objective	No.	Flow Process/Function	Flow Component	Timing
		5-P4	Refer vegetation criteria	Freshes	Any time
		5-P5	Bench formation/ provision of flow over benches	High flow fresh	Any time
		5-P6	Bank scour process	Bankfull	Any time
Vegetation	Maintain/restore distinctive riparian vegetation community and structure including zonation up the bank, and discouraging exotic species	5-V1	Habitat inundation – provision of moisture to benches	High flow fresh	Winter/Spring
		5-V2	Habitat inundation – provision of moisture to floodplain	Overbank	Winter/Spring
		5-V3	Habitat inundation – variability to provide zonation	High flow variability (high flow freshes, bankfull)	Any time (with natural rate of rise and fall)
		5-V4	Habitat regeneration – deposition of sediments on benches	High flow fresh	Any time
		5-V5	Habitat disturbance – bank/bench inundation to provide regeneration niches	High flow	Spring/Summer
		5-V6	Delivery of seeds from upper catchment	High flow	Any time
		5-V7	Prolonged inundation of bank and benches to disadvantage native terrestrial species	Bankfull	Winter/Spring
		5-V8	Prevent over colonisation of instream vegetation	High flow fresh	Anytime
		5-V9	Prolonged inundation of bars to disadvantage terrestrial species	High flow	Continuous over Winter

Reach Six – Gellibrand River Estuary

Reach 6 extends from the Great Ocean Road through to the Southern Ocean outlet at the mouth of the Gellibrand River near Princetown. Latrobe Creek and Boggy Creek are the two main tributaries to this reach of the river. Sections of the estuary have been zoned for public conservation and research, and there are a number of important plant species in the area.

Hydrology

Streamflow in the estuary is impacted by upstream diversions at the North and South Otway Pump Stations. This largely accounts for the average annual streamflow reduction of 16,165 ML (approximately 5.4%) from natural conditions.

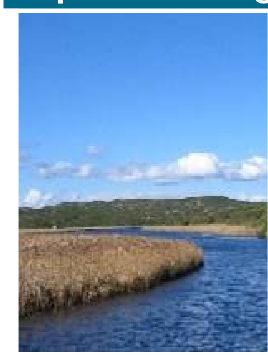
The greatest reductions are evident in the low flow months of December through to May, with a reduction in 50^{th} percentile summer flow from 209 ML/day under natural conditions to 159 ML/day under current conditions. The higher flows are not significantly impacted under the current flow regime.

Physical Form

The Gellibrand River estuary has been classified as a wave dominated estuary. These estuaries typically have low level of marine influence as a result of a restricted bar at the mouth of the system. The estuary system is linear in shape and does not include a wide lake or lagoon. As a consequence wind is not a major influence on destratification of saline layers and mixing is largely controlled by freshwater inflows from the upstream reaches.

The frequency and duration of closure of the estuary bar has a significant impact on water quality ecological processes within the estuary. The opening and closing of the bar is controlled under natural conditions by freshwater inflows to the system and ongoing coastal processes.

Aquatic Ecology and Water Quality



Many estuarine organisms require water of a particular salinity and with sufficient dissolved oxygen to occur at sites for spawning and egg placement. Adequate winter flows are therefore required to flush deep salty water from the estuary and avoid anoxic conditions from developing. Summer/autumn flows are also required to maintain estuarine circulation and remove salt water from the underlying wedge. Constriction of the estuary mouth reduces the effectiveness of this process and may accelerate deep water deoxygenation in turbid estuaries. This can lead to a number of undesirable impacts on ecosystems, such as interference with the migration of fish species into or through the estuary. Long periods of closure may also encourage growth in algal populations.

Vegetation

The estuary is surrounded by EVC 10 Estuarine Wetland in the permanently inundated areas and EVC 53 Swamp Scrub (both Warrnambool Plain Bioregion) away from the permanent water and upstream. The vegetation in the Wetland EVC's is determined by the fluctuating salinity and recruitment is driven by flooding episodes desirable at approximately 5 year intervals. The swamp scrub however regenerates with continuous recruitment.

Summary of Condition for Reach Six

The estuary of the Gellibrand River is in moderate condition. One site has been included in the recent Index of Stream Condition (ISC) assessments where the condition rated highest in physical form and provision for aquatic life. Hydrology (particularly high flow) is modified from natural catchment conditions with most of the change occurring during the summer and autumn periods. Seasonality of flows remain the same as natural conditions.

5 Biodiversity and Ecosystem Criteria for Environmental Objectives

Environmental and flow objectives were identified by the Technical Panel as a result of the information gathered, field trips and workshop discussion.

Criteria were considered as both Biodiversity Processes and Ecosystem Processes defined as follows:

- Biodiversity processes deal with individual biological processes (such as spawning, recruitment, migration, germination, habitat requirements etc) that are required to achieve the overall objective for a key listed or threatened fauna within the reach, flora and fauna of value, or those with a strong relationship with flow.
- Ecosystem processes are processes that occur in an aquatic environment that are not so easily associated with a biodiversity asset to such a specific degree. These are processes with indirect links to the asset (operating through a number of intermediate steps) or those that are known to have more general ecological benefits (such as carbon cycling and the entrainment of leaf litter off the stream banks or floodplain). It is well known that in many aquatic ecosystems, entrained leaf litter and its contribution to carbon cycling is a vital component of ecosystem functioning, but it would be difficult to associate it with a particular life cycle stage or a physical habitat for many assets.

From the biodiversity and ecosystem processes, the Technical Panel was able to determine specific flow components that were required to satisfy one or many of the criteria. Flow components identify the important flow components that would need to be present in order to achieve the Biodiversity and Ecosystem processes (that will then achieve the Environmental Flow Objective).

Table 5-1 Summary of Biodiversity and Ecosystem Process Draft Criteria for the Gellibrand River Catchment

Biodiversity Objective	No.	Flow Process	Draft Flow Criteria	
			Flow Component	Timing
Main self sustaining populations of macroinvertebrates	1a	Habitat availability (inundation of leaf packs, instream vegetation, and/or shallow runs from edge to edge)	Low flow	All year
	1b	Water quality maintenance	Low flow	Low flow season
	1c	Refresh water quality and flush habitat	Low flow fresh	Low flow season
	1d	Flush habitat	High flow fresh	High flow season
	1e	Entrain terrestrial carbon	Overbank	High flow season
Maintain self sustaining fish populations	2a	Habitat availability (Australian Grayling, River Blackfish)	Low flow	All year
	2b	Habitat availability (small-bodied fish)	Low flow	All year

Biodiversity Objective	No.	Flow Process	Draft Flow Criteria	
			Flow Component	Timing
	2c	Localised fish movement between habitats (Australian Grayling, River Blackfish)	Low flow fresh	Early low flow season
	2d	Localised fish movement between habitats (small-bodied fish)	Low flow fresh	Late high flow season
	2e	Migration movement of small-bodied migratory fish	High flow	Early high flow season
	2f	Migration stimulation of small-bodied migratory fish	High flow fresh	Early high flow season
	2g	Spawning stimulation of small-bodied resident fish	High flow fresh	Late high flow season
	2h	Water quality maintenance	Low flow	Low flow season
	2i	Refresh water quality and flush habitat	Low flow fresh	Low flow season
	2j	Flush habitat	High flow fresh	High flow season
Maintain water quality to meet environmental objectives	3a	Flushing of pools	Low flow fresh	Summer
Prevent channel encroachment or enlargements	4a	Maintain frequency and duration of mid bank to overbank flows within 20% of natural	High flow freshes and overbank	Anytime
Prevent infilling of scour holes	4b	No change in the occurrence and timing of events that create scour holes of dimension sort by ecologists	Freshes	Anytime
Maintain floodplain evolution	4c	Provide natural frequency of overbank flows to maintain sediment accession into the floodplain	Overbank	Anytime
Prevent instream vegetation colonisation	4d	Refer vegetation criteria	Freshes	Any time
Maintain/restore distinctive riparian vegetation community and structure, including zonation up the bank	5a	Habitat inundation – provision of moisture to benches	High flow fresh	Winter/Spring
	5b	Habitat inundation – provision of moisture to floodplain	Overbank	Winter/Spring
	5c	Habitat inundation – variability to provide zonation	High flow variability (High flow freshes, bankfull)	Any time (with natural rate of rise and fall)
	5d	Habitat regeneration - deposition of sediments on benches	High flow fresh	Any time

Biodiversity Objective	No.	Flow Process	Draft Flow Criteria	
			Flow Component	Timing
	5e	Habitat disturbance - bank/bench inundation to provide regeneration niches	High flow	Spring/Summer
	5f	Delivery of seed from upper catchment	High flow	Any time
	5g	Prolonged inundation of bank and benches to disadvantage native terrestrial species	Prolonged bankfull flow	Winter/Spring
	5h	Prevent over colonisation of instream and semi-aquatic vegetation	High flow fresh	Spring/Summer
Replacement of exotic terrestrial species with native shrubs and ground cover	5i	Prolonged inundation of bank and benches to disadvantage terrestrial exotic species	Prolonged bankfull flow	Winter/Spring
Prevent sedimentation and entrain debris	5j	Maintain frequency and duration of mid bank to overbank flows to within 20% of natural	High flow freshes and overbank	Anytime
Maintain health of above bank vegetation	5k	Ensure near natural rates of overbank and high flows within 20% of natural	High flows to overbank	Anytime

6 References

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Koehn, J. D. and O'Connor, W. G. (1990) *Biological Information for Management of Native Freshwater Fish in Victoria.* Government Printer, Melbourne.

LYDEFTP (2004) *Environmental flow determination for the Little Yarra and Don Rivers: Final Recommendations*. Unpublished Report by Little Yarra and Don Rivers Environmental Flow Technical Panel, to Melbourne Water Corporation, Melbourne.

Photo – Front Cover (Platypus): Courtesy Healesville Sanctuary

Tilleard J.W. (2001) *River channel adjustment to hydrologic change*. PhD Thesis. University of Melbourne.

Appendix A
Assets and Key Threats identified by the Advisory Group (21 July 2005)

Gellibrand River Values

- Fish values – River Blackfish, Tupong, Eels, Brown Trout
- Commercial fishing licence for Eels
- Estuary Perch, Bream
- Platypus
- Tea tree swamps (Rusty Creek, Quinlin Creek)
- Recreational fishing (River Blackfish, Brown Trout)
- Significant bird populations
- Good vegetation cover
- Water supply for towns, farms, security of supply
- Geomorphic form of the river – aesthetic
- Native aboriginal population
- Spring flows
- Water quality
- Very few, if any carp
- Pristine environments, aesthetic value

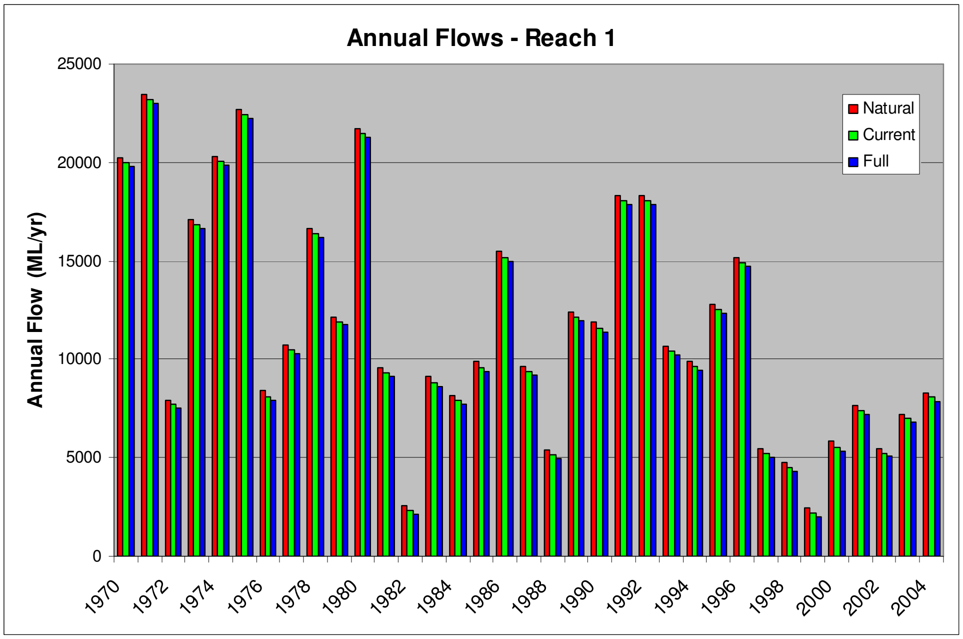
Threats to Values

- Kennedy's Creek water quality
- Tree plantations – impacts on quantity, quality, sediment release to system
- Estuary recreational pressures
- Willows
- Groundwater extractions – Wannon Water's new extractions
- SWW direct pumping from stream, & Barwon Water in top end of system – no off-stream storage – increasing demand for water outside of catchment (urban growth – coastal growth)
- Farm crossings
- In-stream barriers that are not provided with passage
- Cattle access causing quality sediment issues
- Bird nesting areas
- Weeds
- Absentee landholders
- Drought
- Spraying related to plantations (herb and insect)

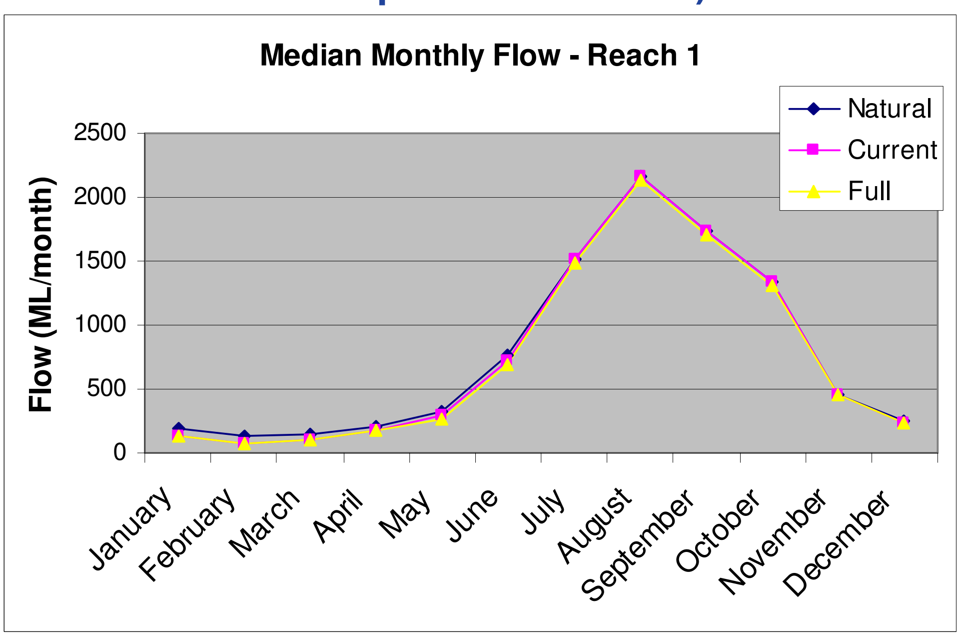
Appendix B
Waterway Condition and Processes
Hydrology

Reach 1: Love Creek Catchment

Annual Flows (natural, current and full development scenarios)

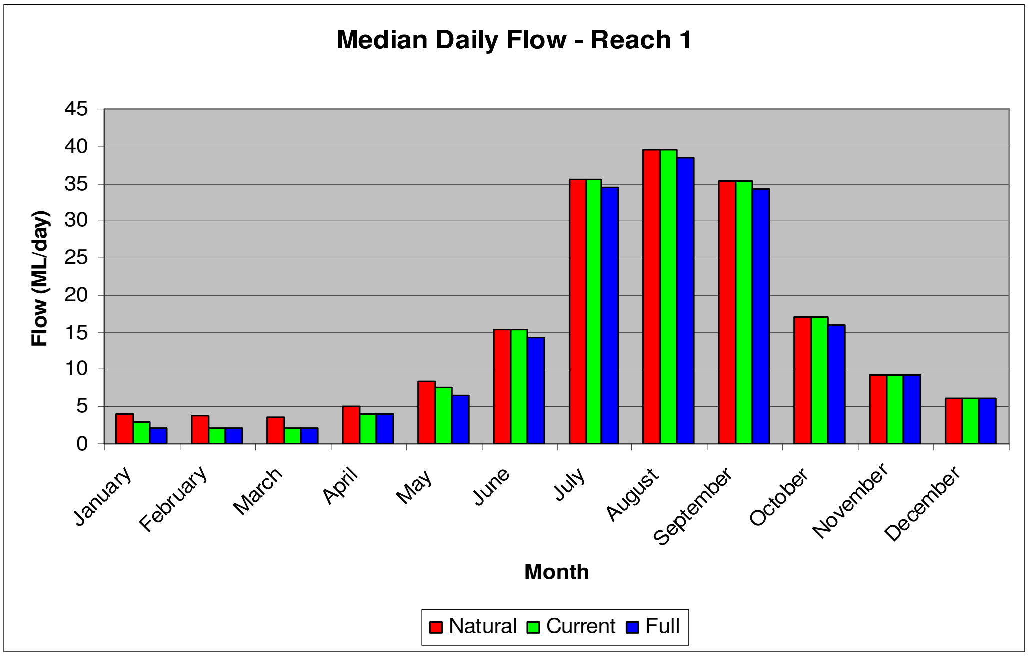


Median Monthly Flows (natural, current and full development scenarios)

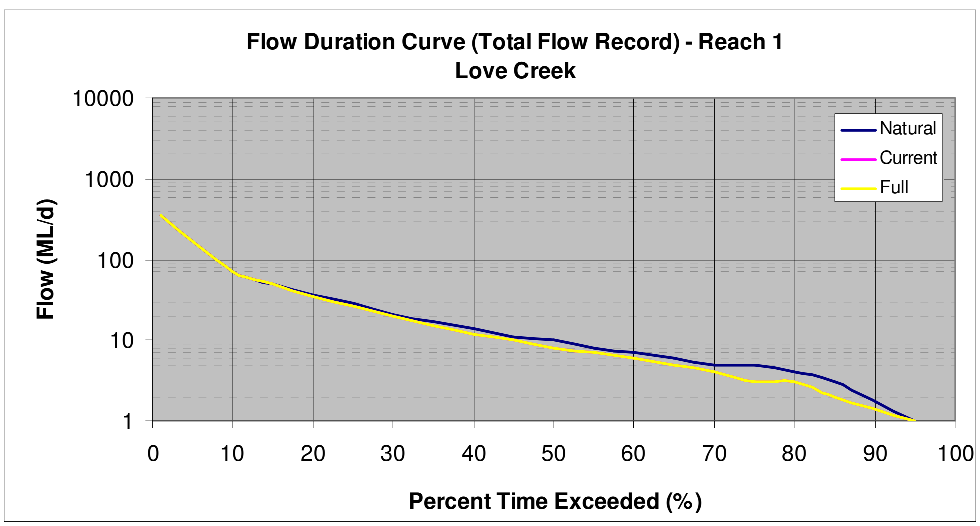


Reach 1: Love Creek Catchment

Median Daily Flows (natural, current and full development scenarios)



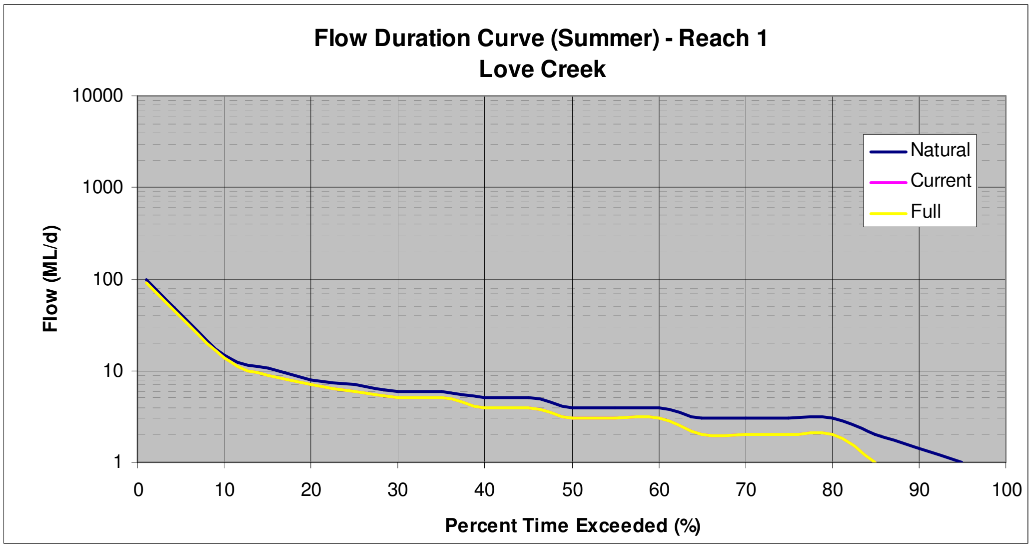
Flow Duration Curve (Total Flow Record)



Note: Current catchment configuration is equal to the full development scenario

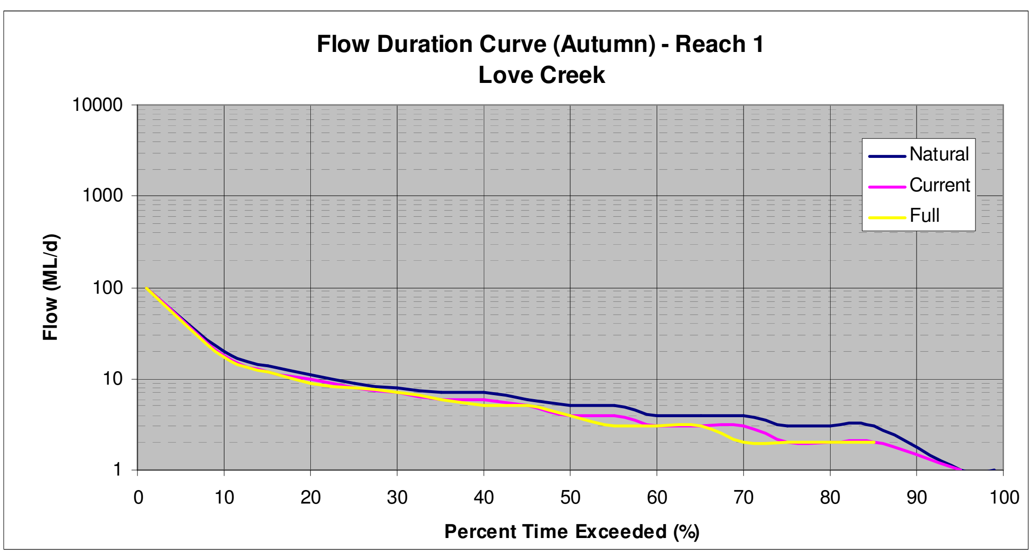
Reach 1: Love Creek Catchment

Seasonal Flow Duration Curve (Summer)



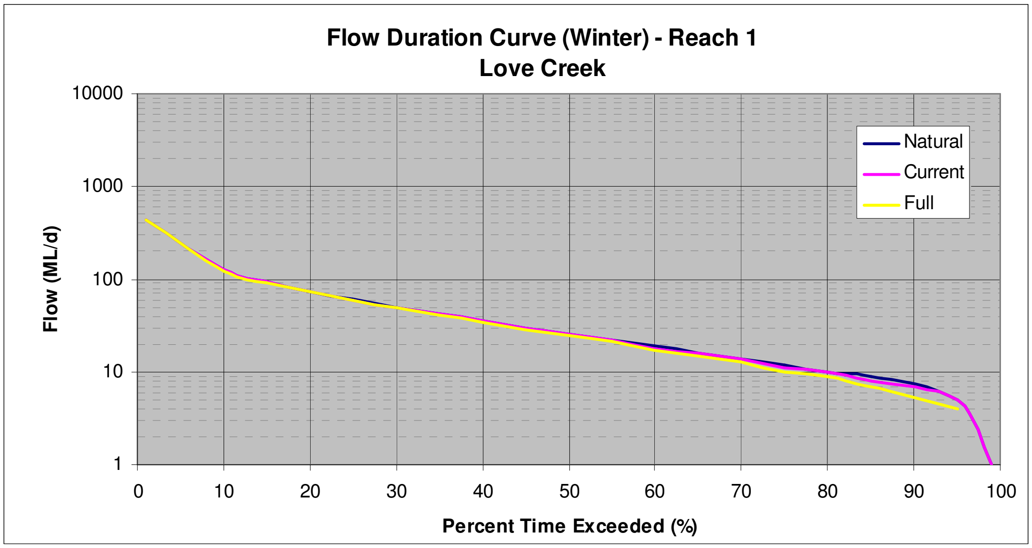
Note: Current catchment configuration is equal to the full development scenario

Seasonal Flow Duration Curve (Autumn)

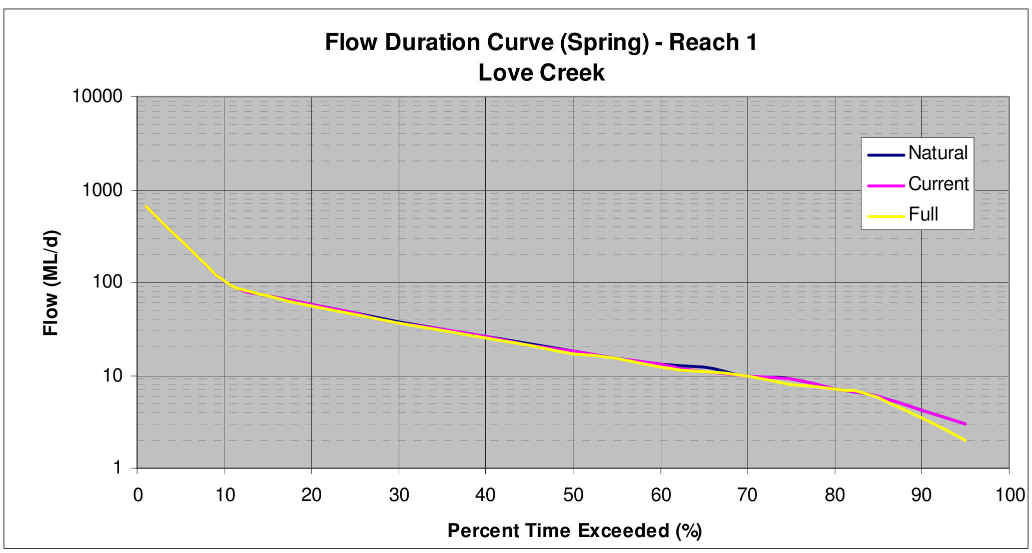


Reach 1: Love Creek Catchment

Seasonal Flow Duration Curve (Winter)

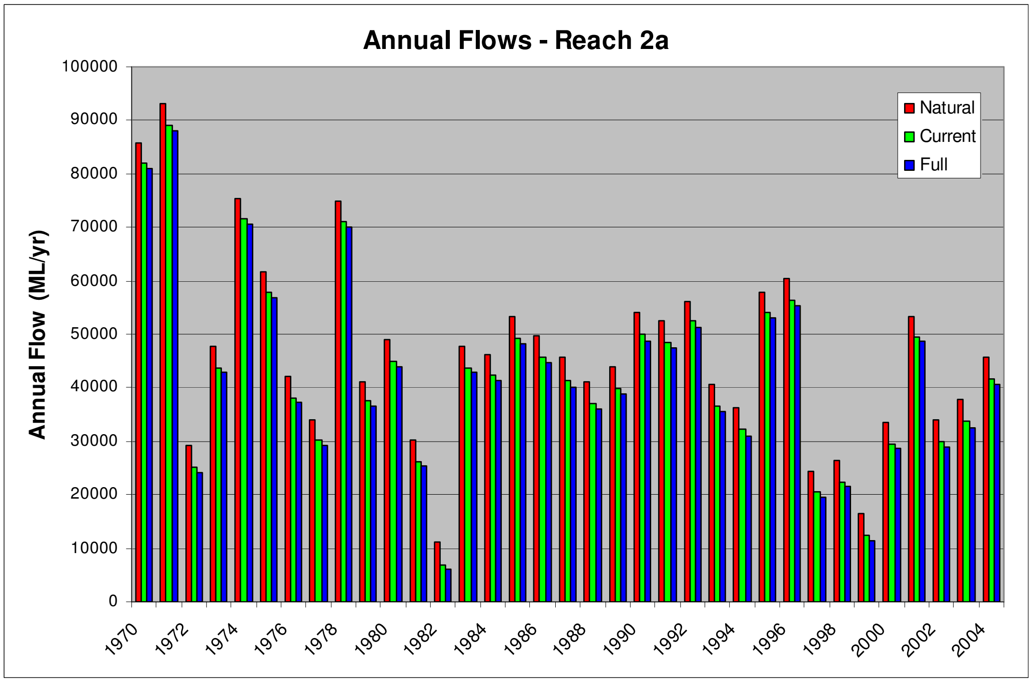


Seasonal Flow Duration Curve (Spring)

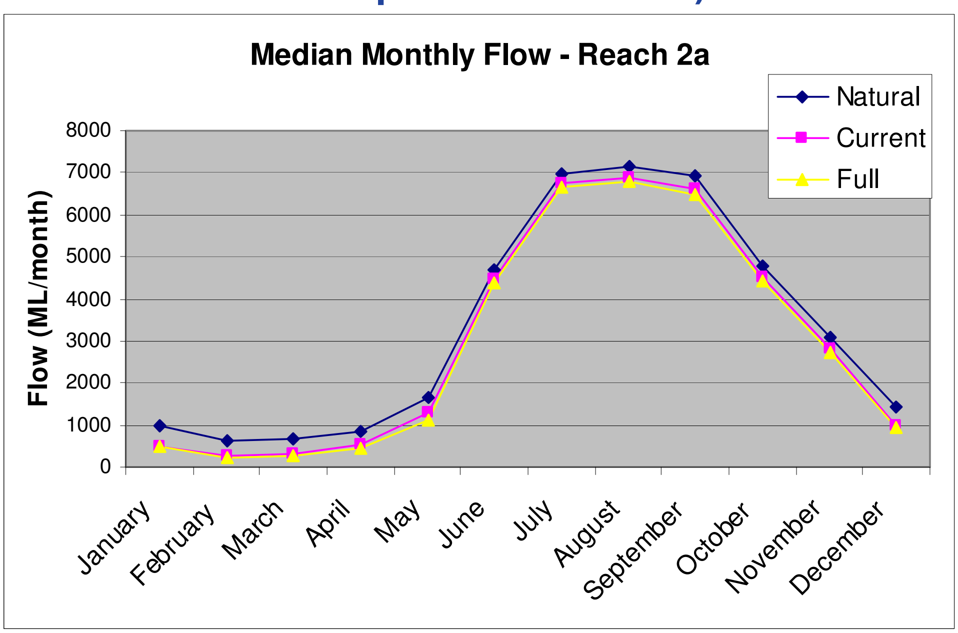


Reach 2a: Upper Gellibrand

Annual Flows (natural, current and full development scenarios)

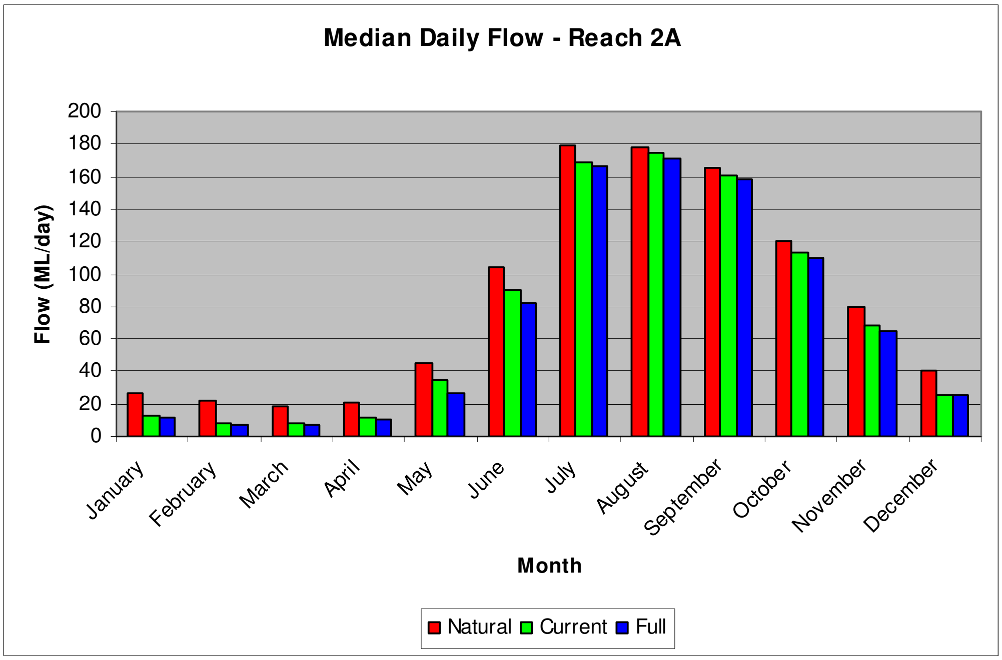


Median Monthly Flows (natural, current and full development scenarios)

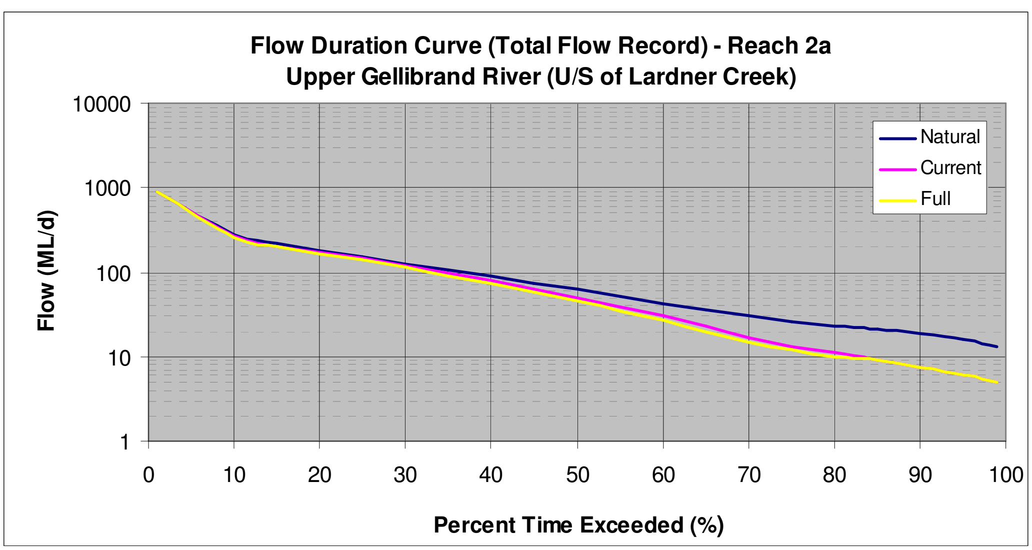


Reach 2a: Upper Gellibrand

Median Daily Flows (natural, current and full development scenarios)

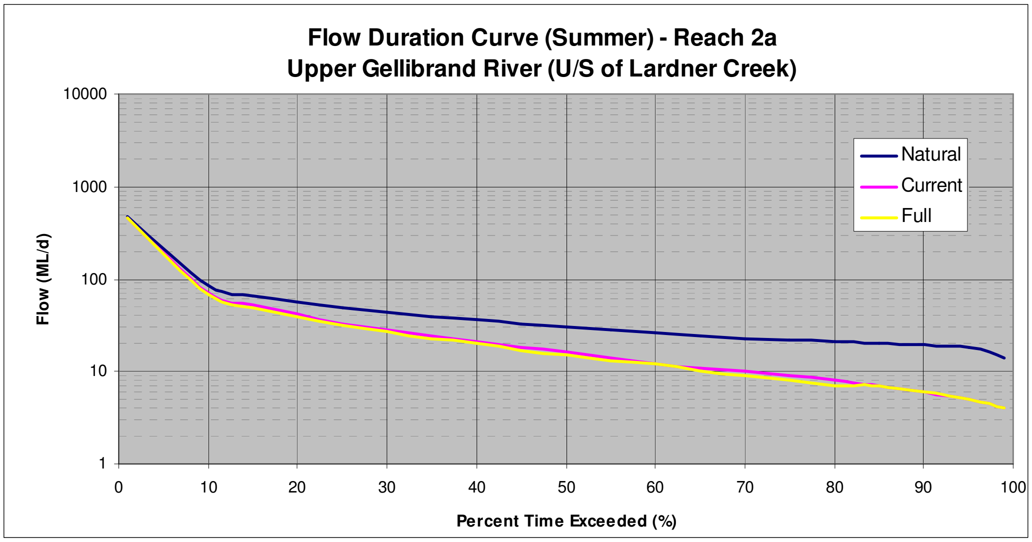


Flow Duration Curve (Total Flow Record)

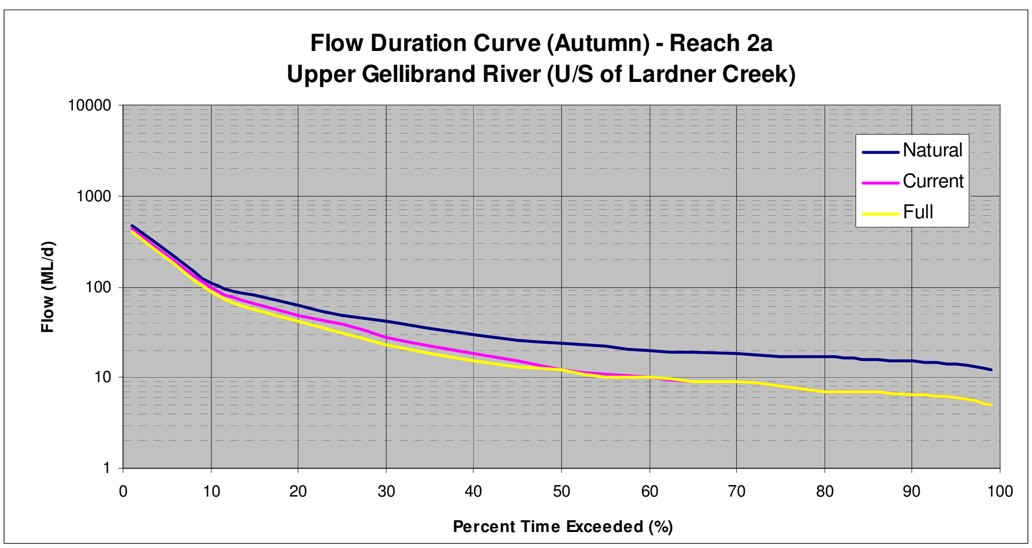


Reach 2a: Upper Gellibrand

Seasonal Flow Duration Curve (Summer)

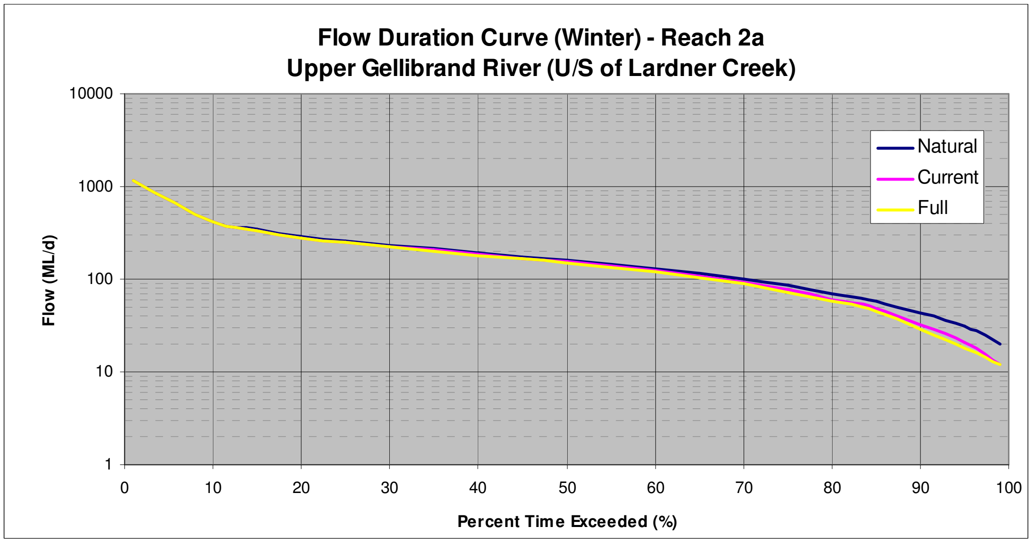


Seasonal Flow Duration Curve (Autumn)

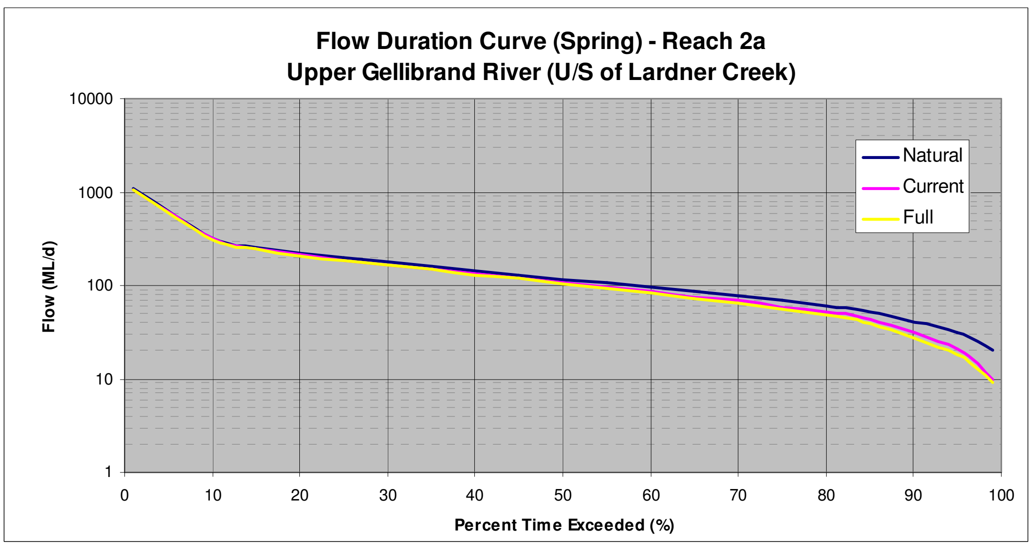


Reach 2a: Upper Gellibrand

Seasonal Flow Duration Curve (Winter)

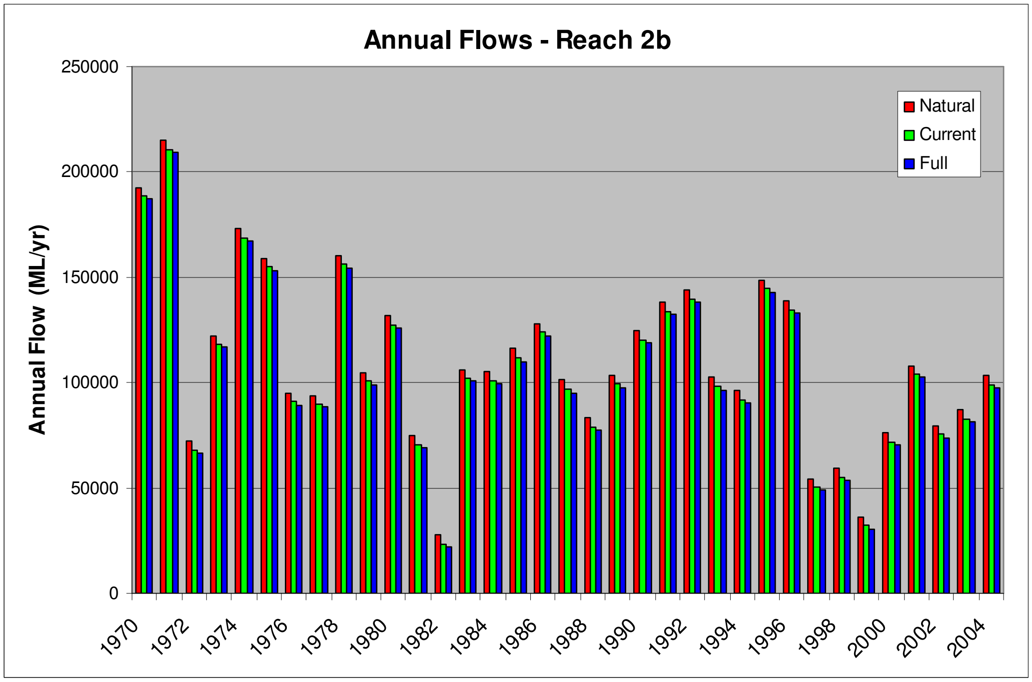


Seasonal Flow Duration Curve (Spring)

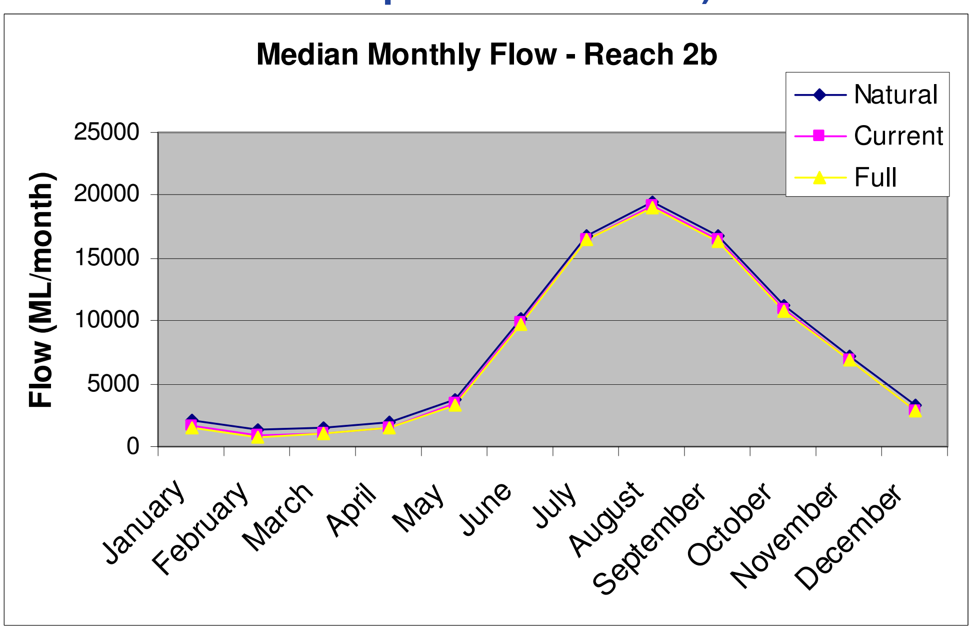


Reach 2b: Upper Gellibrand

Annual Flows (natural, current and full development scenarios)

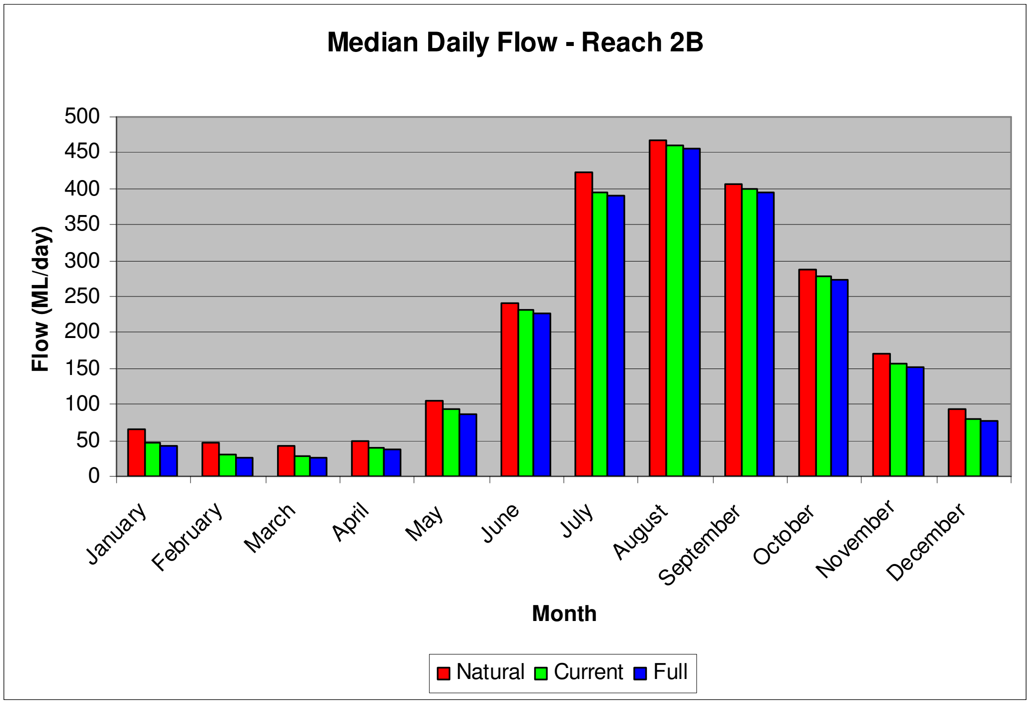


Median Monthly Flows (natural, current and full development scenarios)

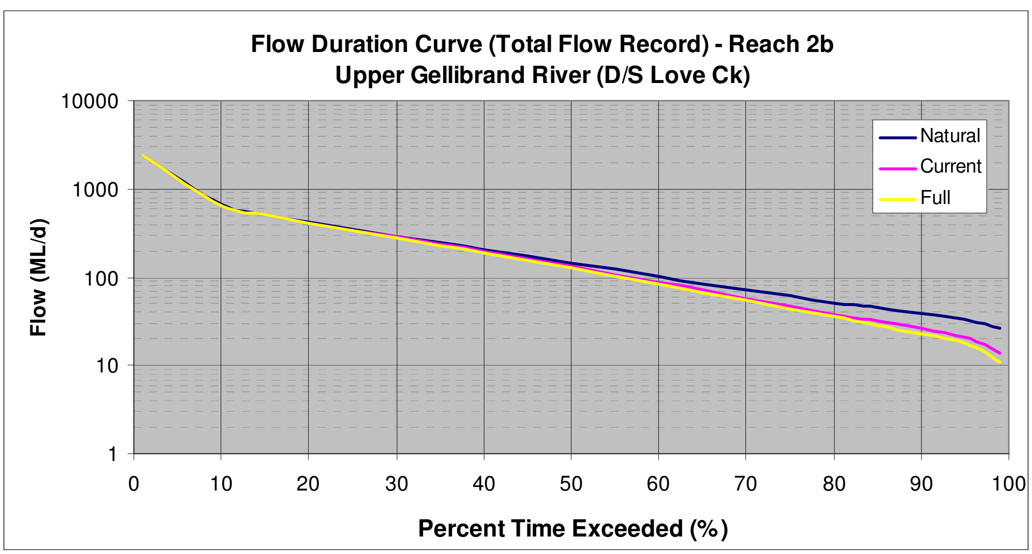


Reach 2b: Upper Gellibrand

Median Daily Flows (natural, current and full development scenarios)

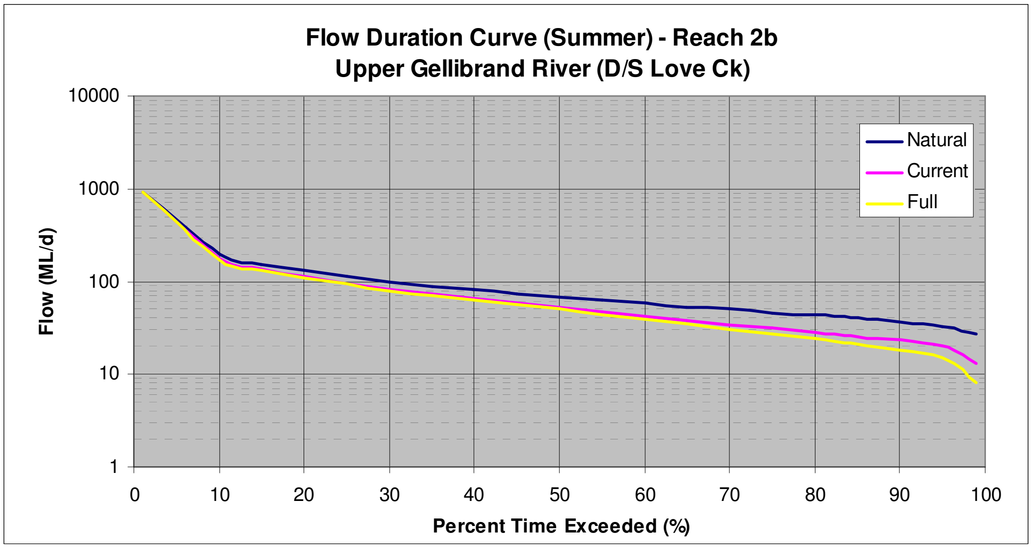


Flow Duration Curve (Total Flow Record)

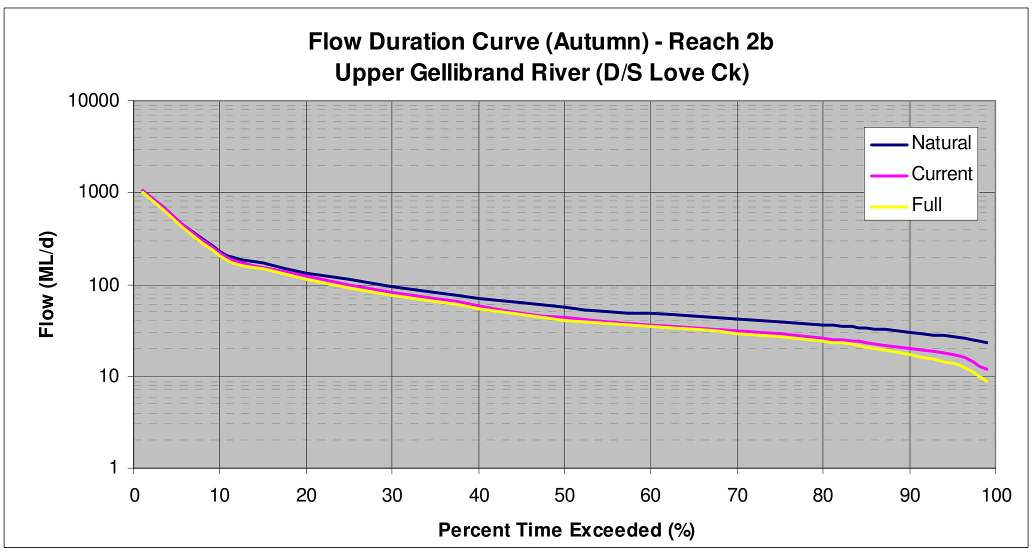


Reach 2b: Upper Gellibrand

Seasonal Flow Duration Curve (Summer)

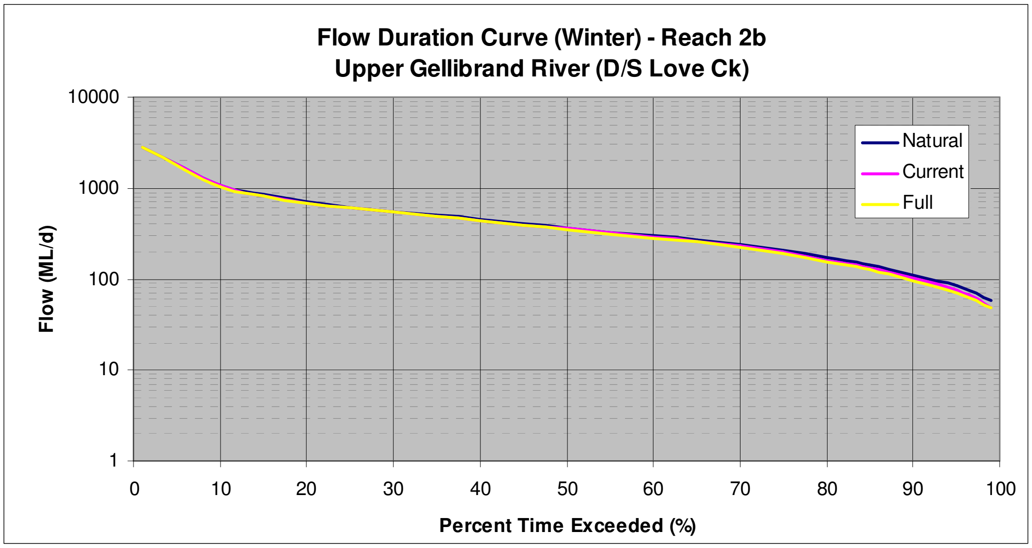


Seasonal Flow Duration Curve (Autumn)



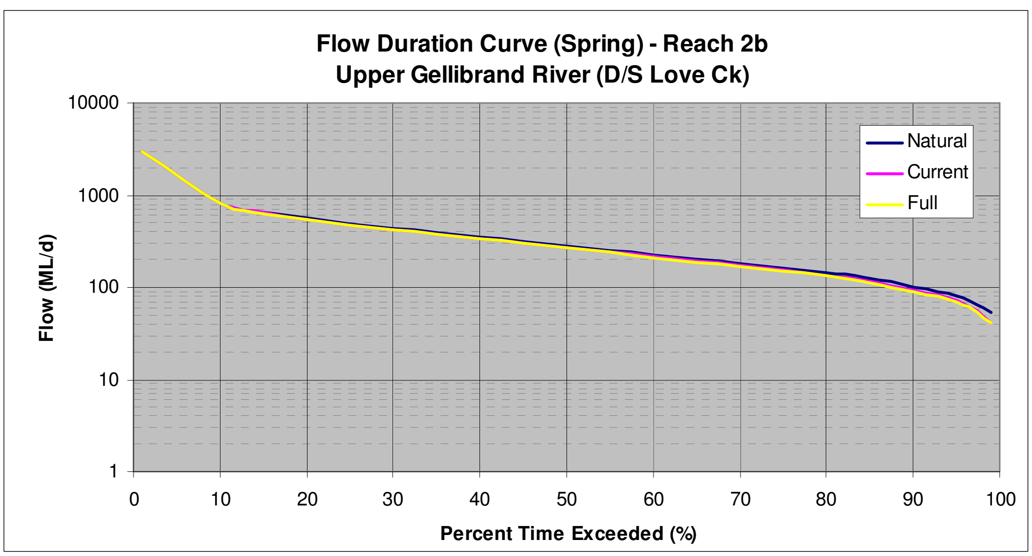
Reach 2b: Upper Gellibrand

Seasonal Flow Duration Curve (Winter)



Note: Current catchment configuration is equal to the full development scenario

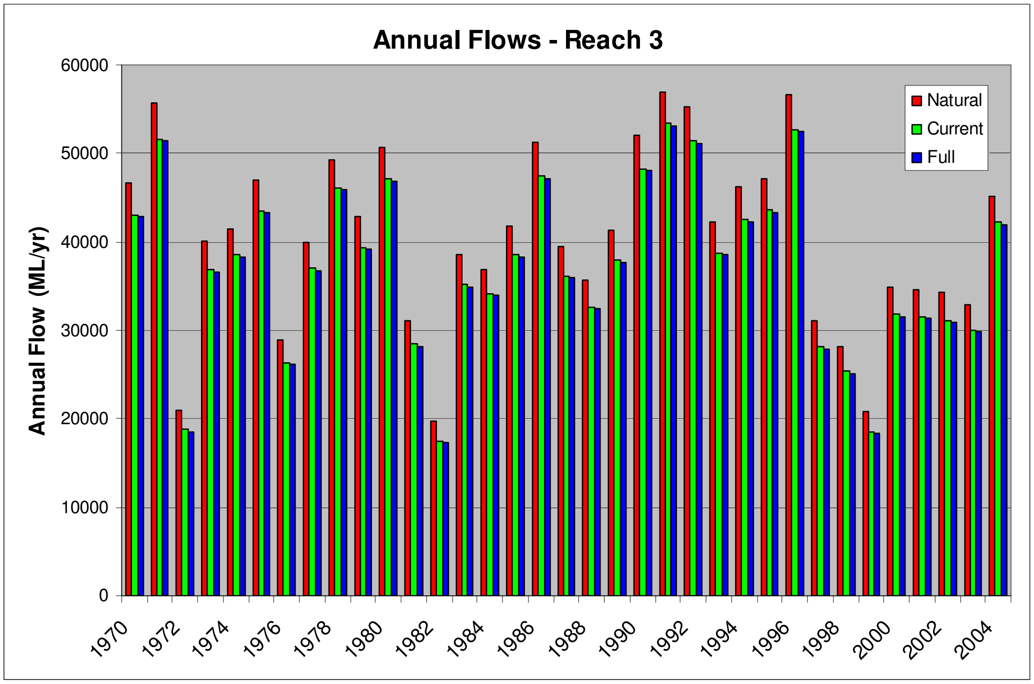
Seasonal Flow Duration Curve (Spring)



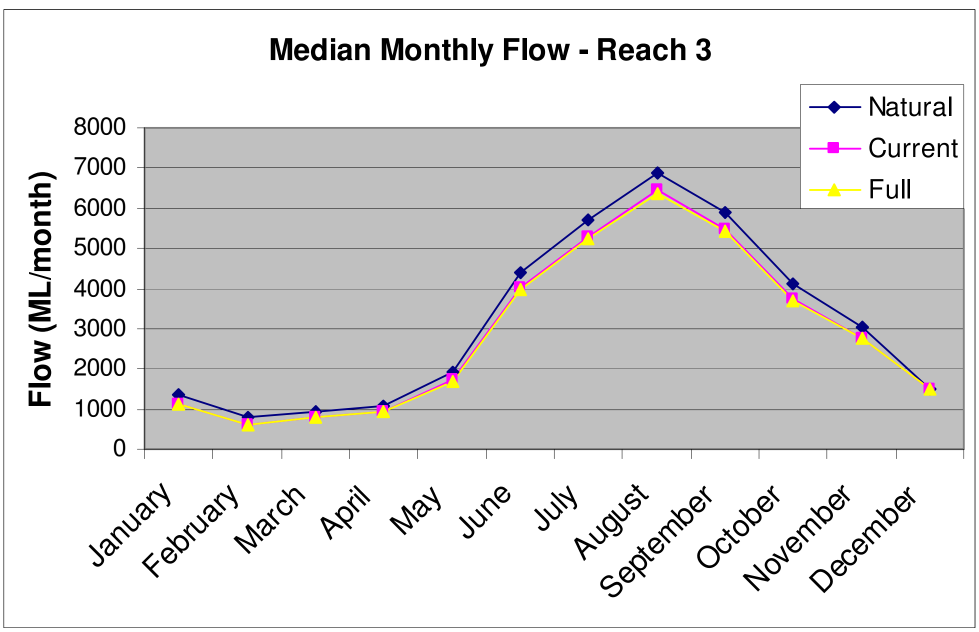
Note: Current catchment configuration is equal to the full development scenario

Reach 3: Carlisle River Catchment

Annual Flows (natural, current and full development scenarios)

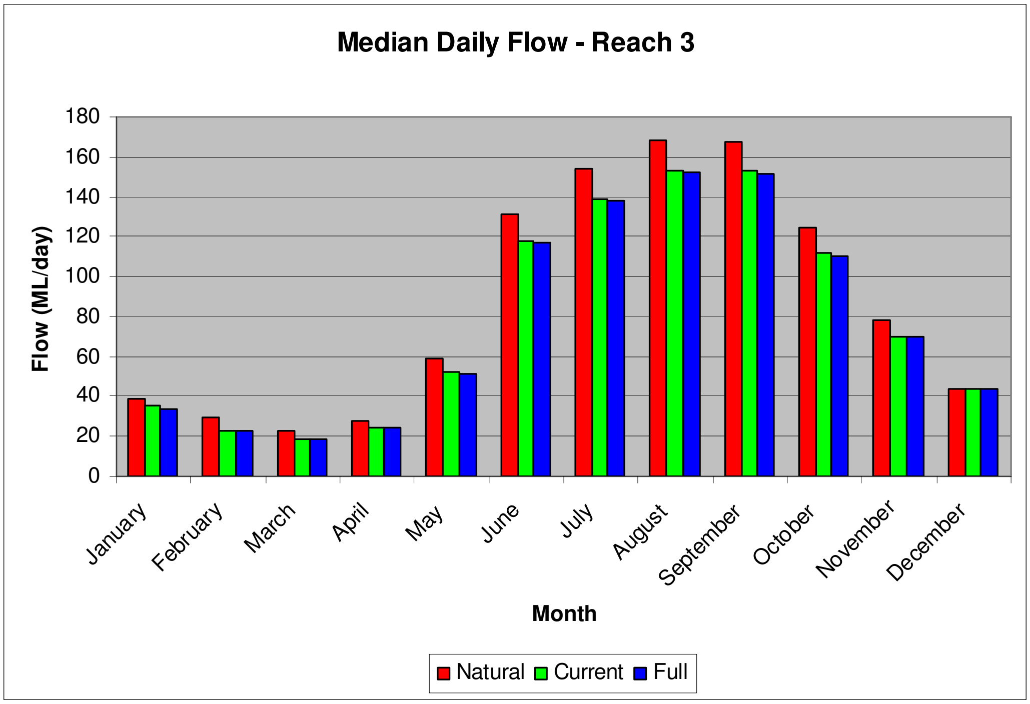


Median Monthly Flows (natural, current and full development scenarios)

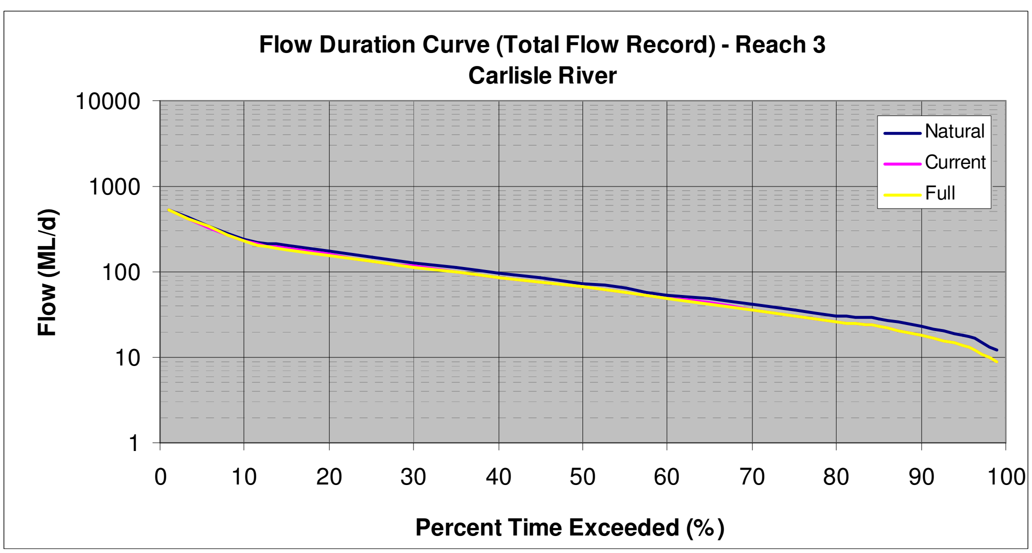


Reach 3: Carlisle River Catchment

Median Daily Flows (natural, current and full development scenarios)



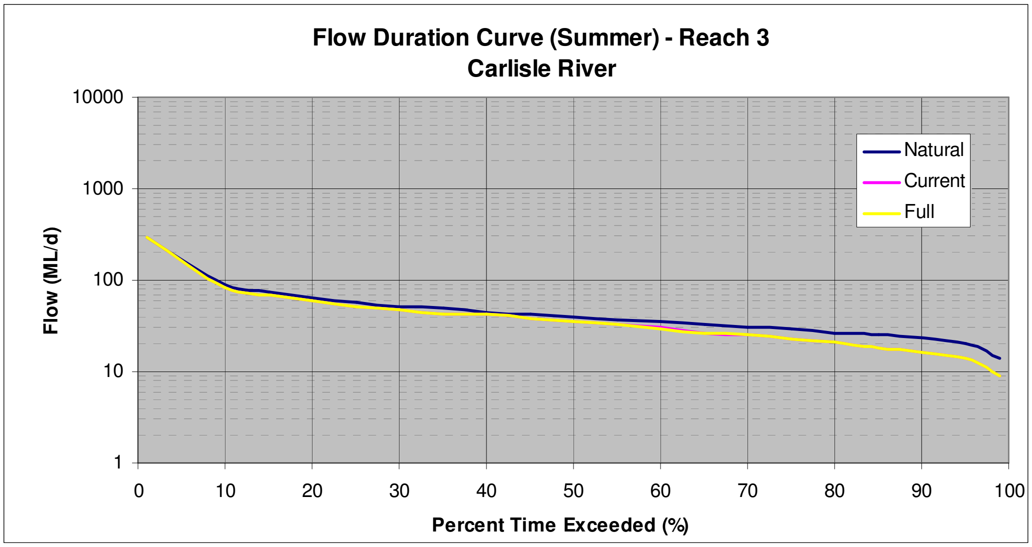
Flow Duration Curve (Total Flow Record)



Note: Current catchment configuration is equal to the full development scenario

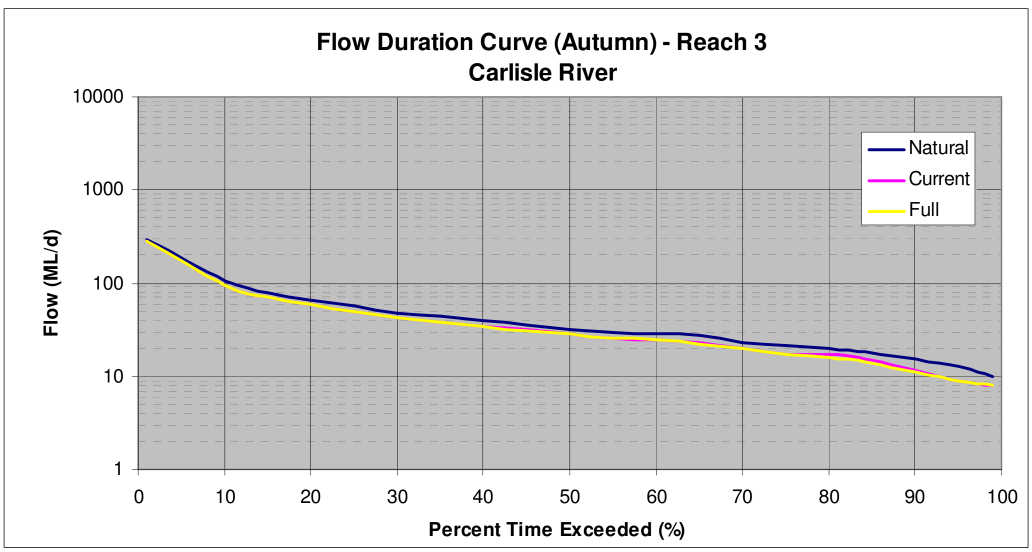
Reach 3: Carlisle River Catchment

Seasonal Flow Duration Curve (Summer)



Note: Current catchment configuration is equal to the full development scenario

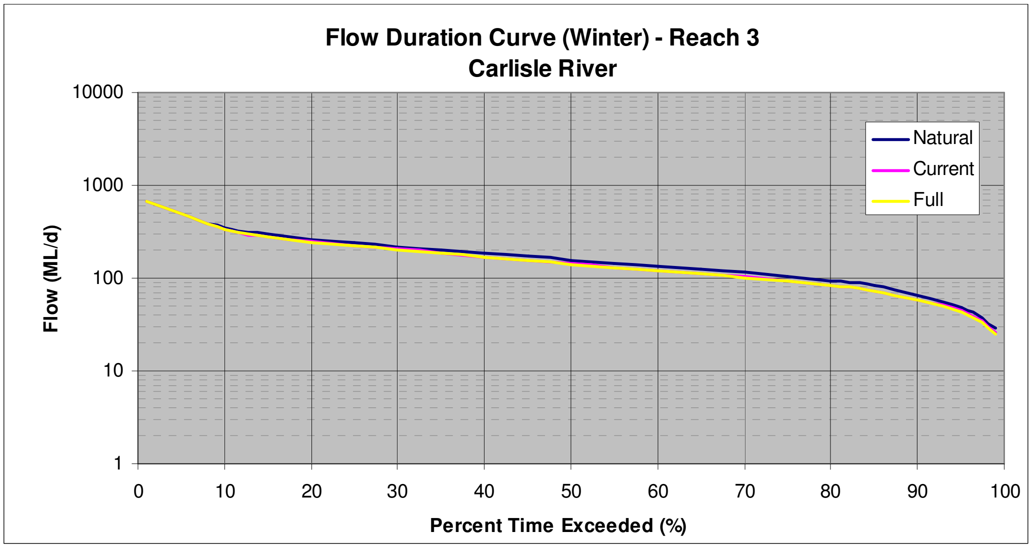
Seasonal Flow Duration Curve (Autumn)



Note: Current catchment configuration is equal to the full development scenario

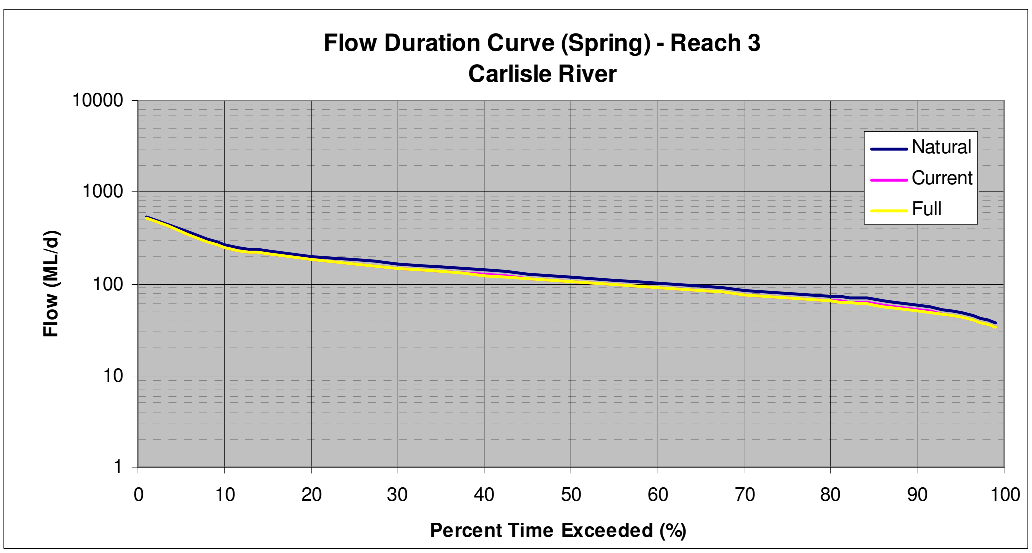
Reach 3: Carlisle River Catchment

Seasonal Flow Duration Curve (Winter)



Note: Current catchment configuration is equal to the full development scenario

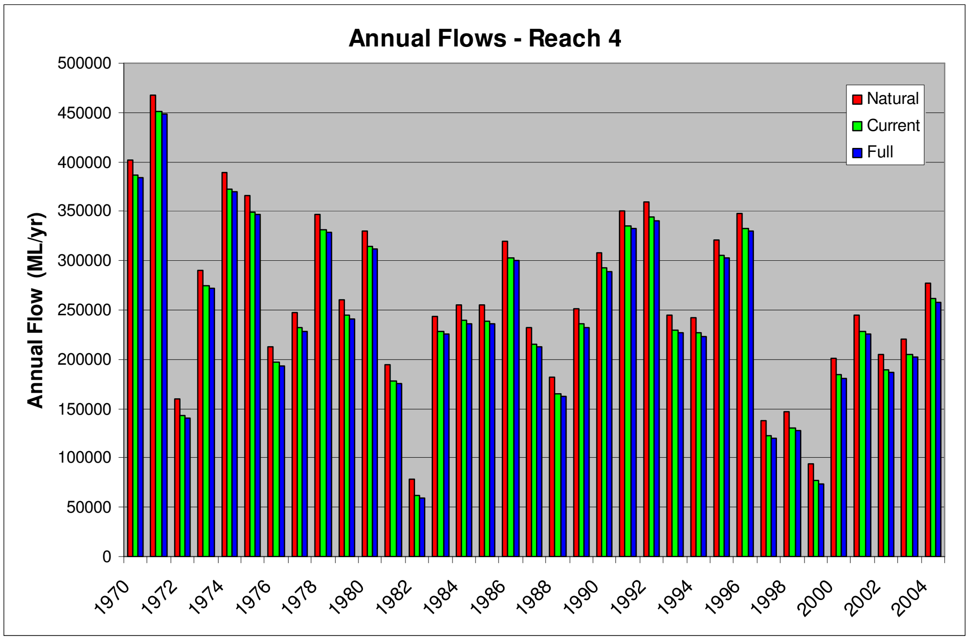
Seasonal Flow Duration Curve (Spring)



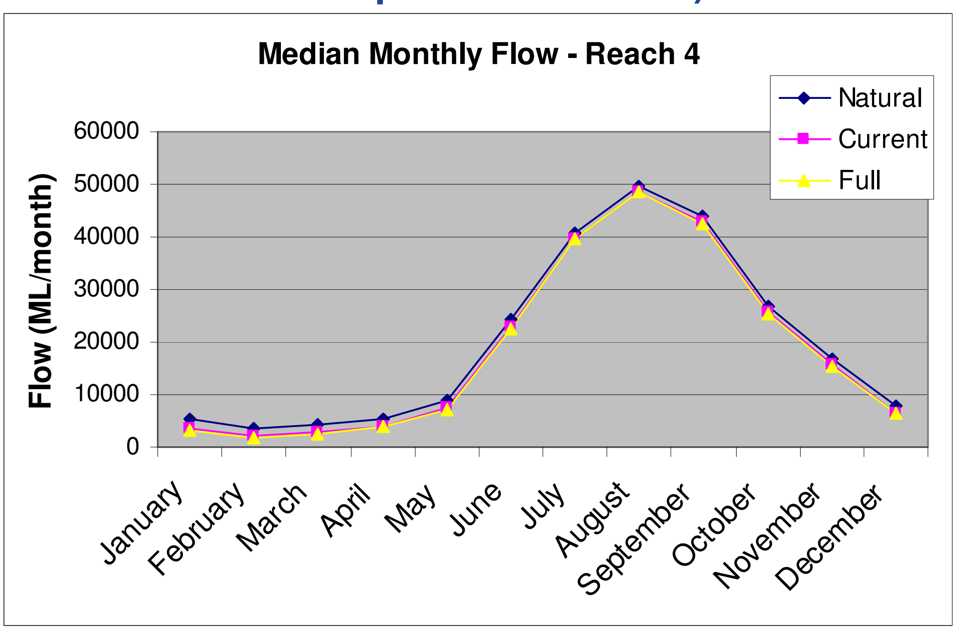
Note: Current catchment configuration is equal to the full development scenario

Reach 4: Gellibrand River

Annual Flows (natural, current and full development scenarios)

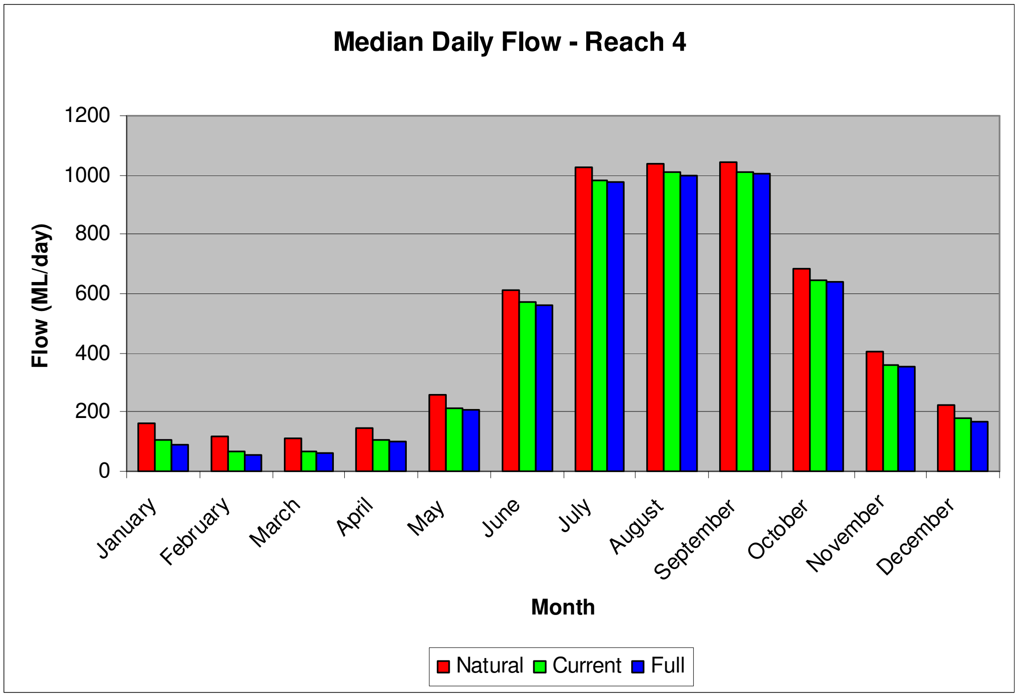


Median Monthly Flows (natural, current and full development scenarios)

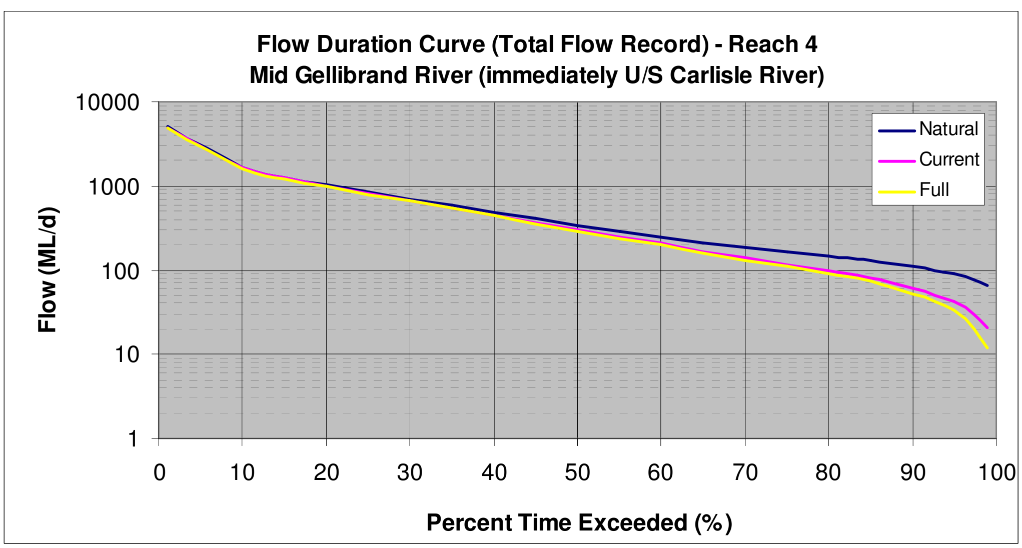


Reach 4: Gellibrand River

Median Daily Flows (natural, current and full development scenarios)

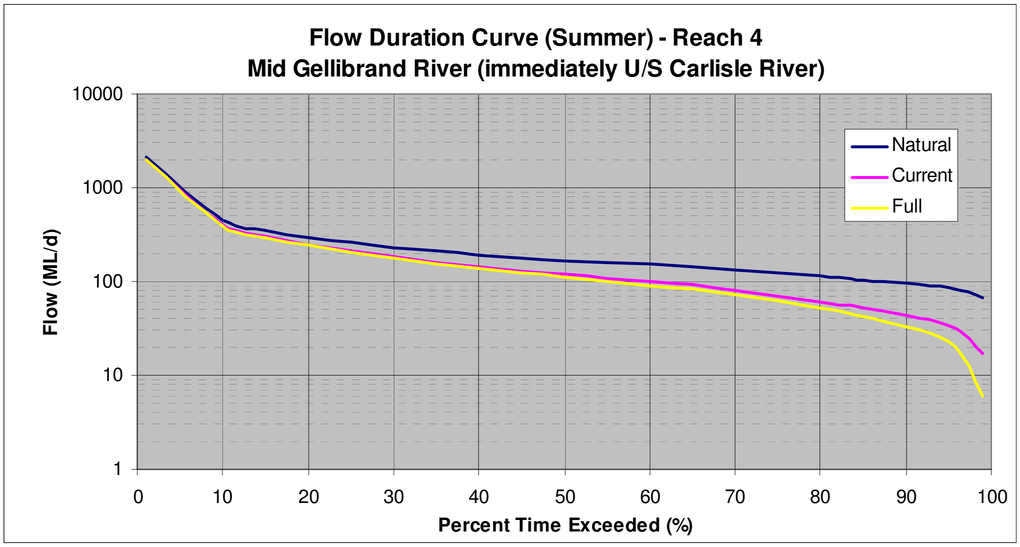


Flow Duration Curve (Total Flow Record)

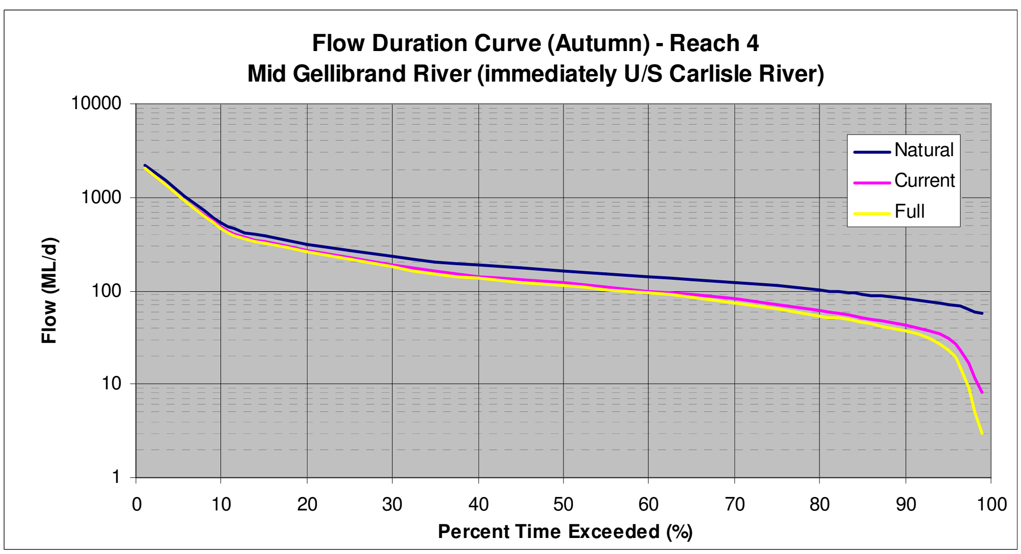


Reach 4: Gellibrand River

Seasonal Flow Duration Curve (Summer)

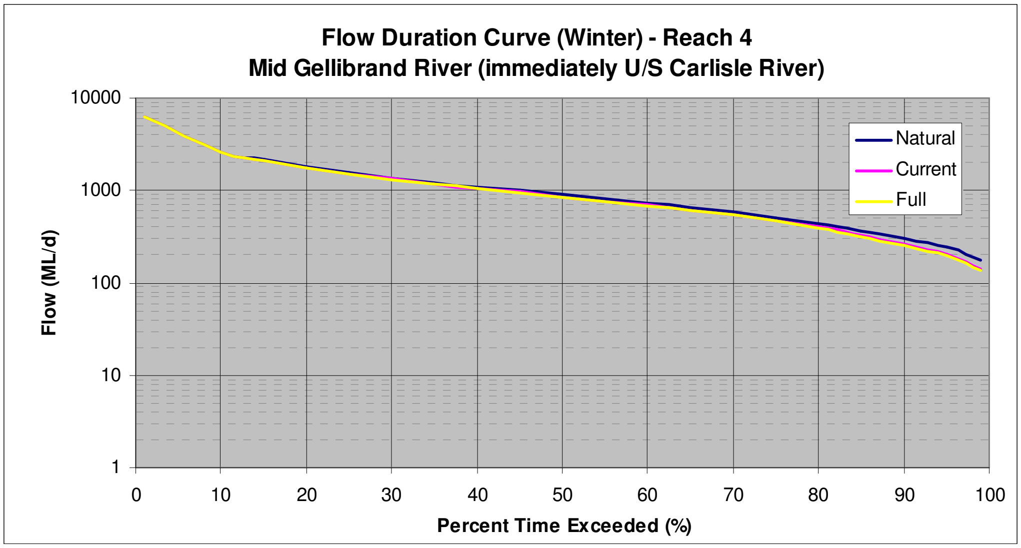


Seasonal Flow Duration Curve (Autumn)



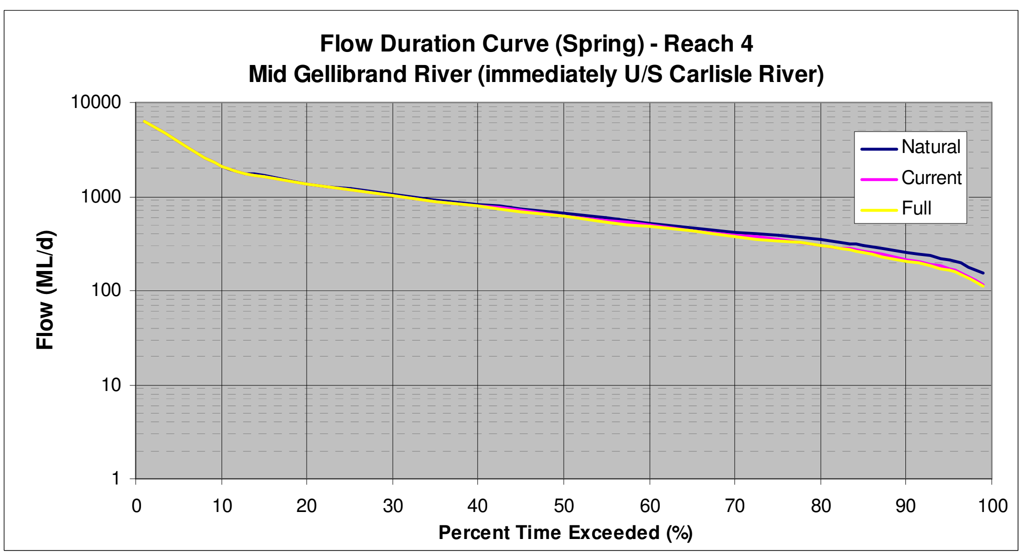
Reach 4: Gellibrand River

Seasonal Flow Duration Curve (Winter)



Note: Current catchment configuration is equal to the full development scenario

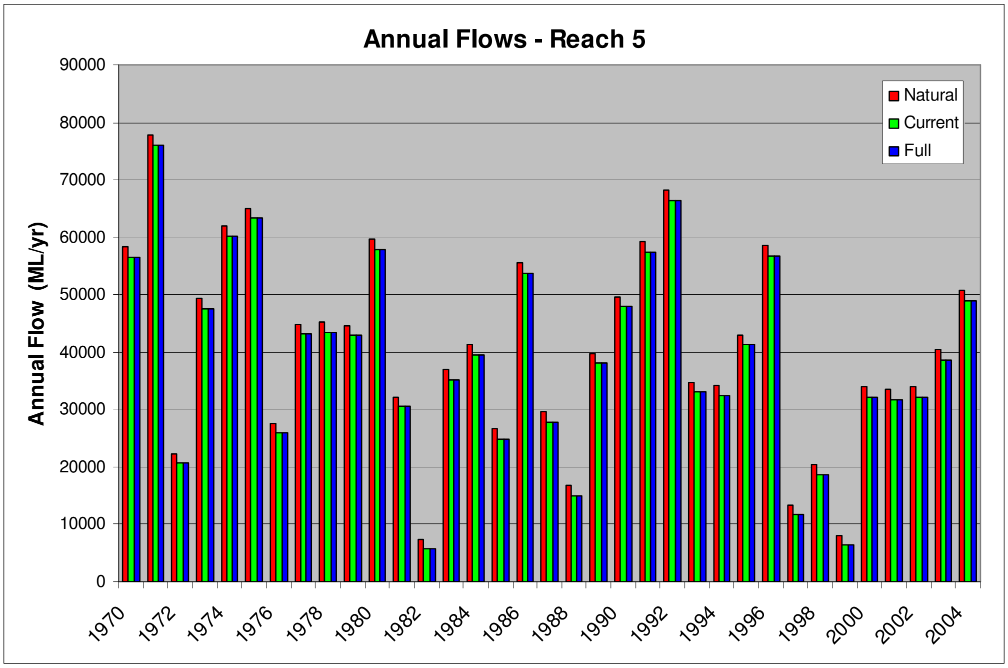
Seasonal Flow Duration Curve (Spring)



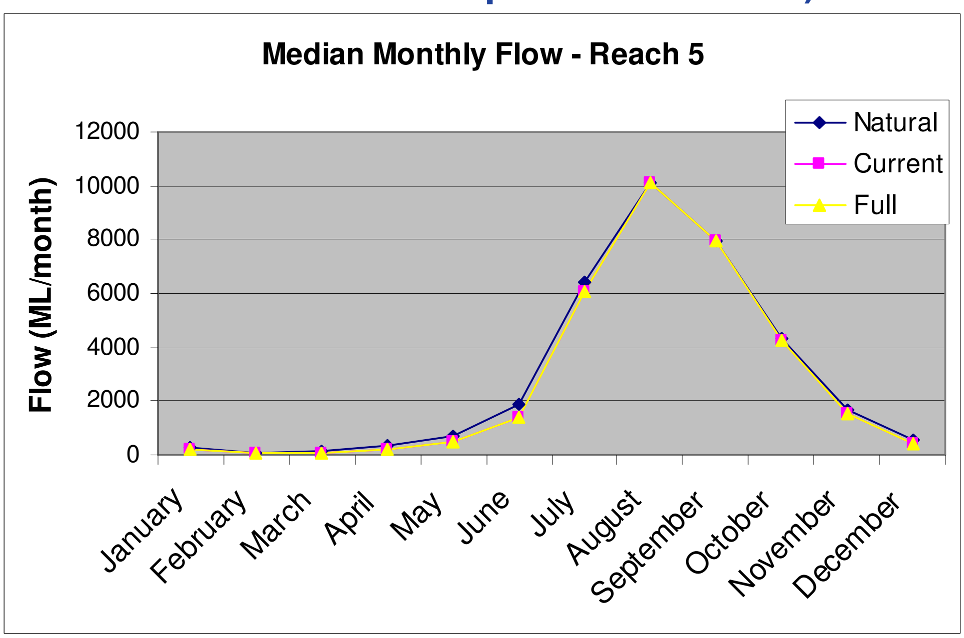
Note: Current catchment configuration is equal to the full development scenario

Reach 5: Kennedy's Creek Catchment

Annual Flows (natural, current and full development scenarios)

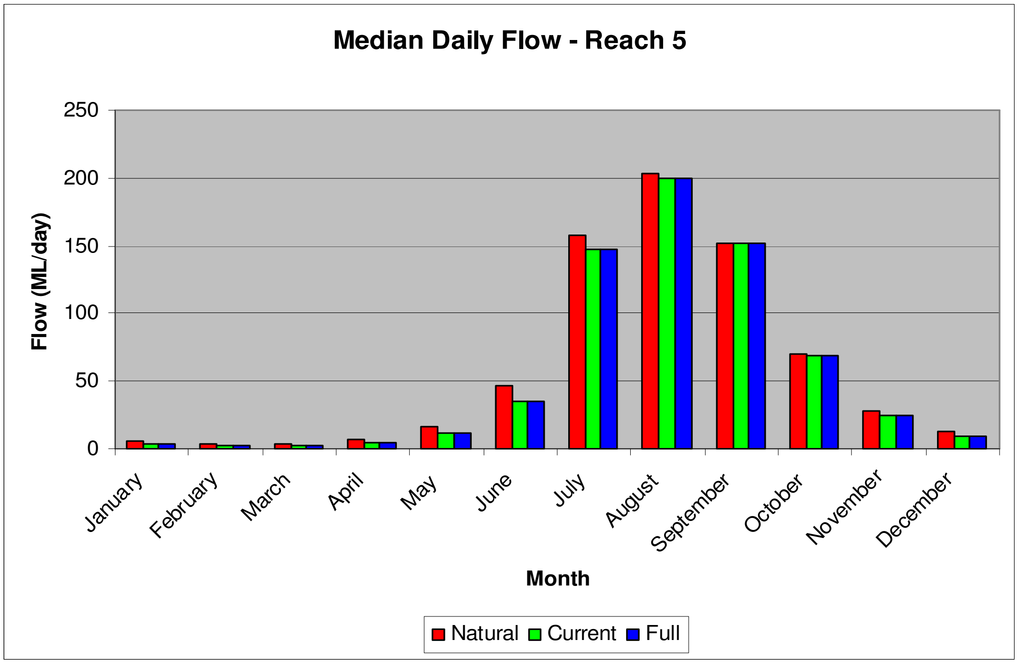


Median Monthly Flows (natural, current and full catchment development scenarios)

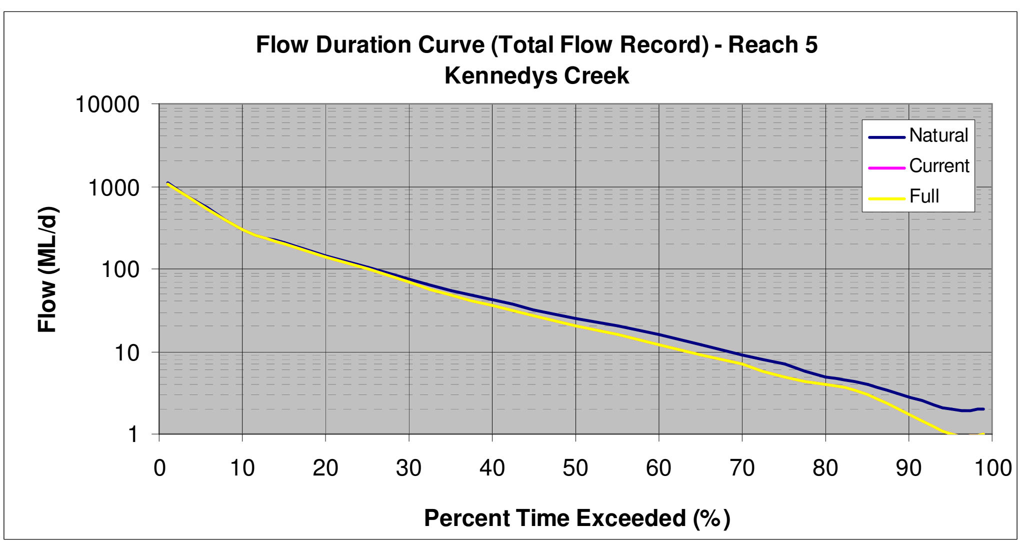


Reach 5: Kennedys Creek Catchment

Median Daily Flows (natural, current and full catchment development scenarios)



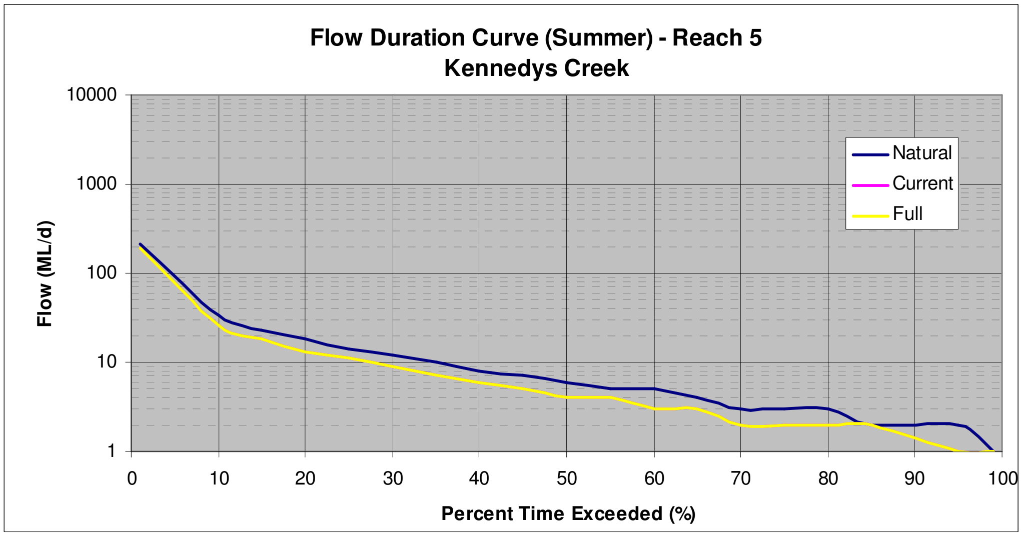
Flow Duration Curve (Total Flow Record)



Note: Current catchment configuration is equal to the full development scenario

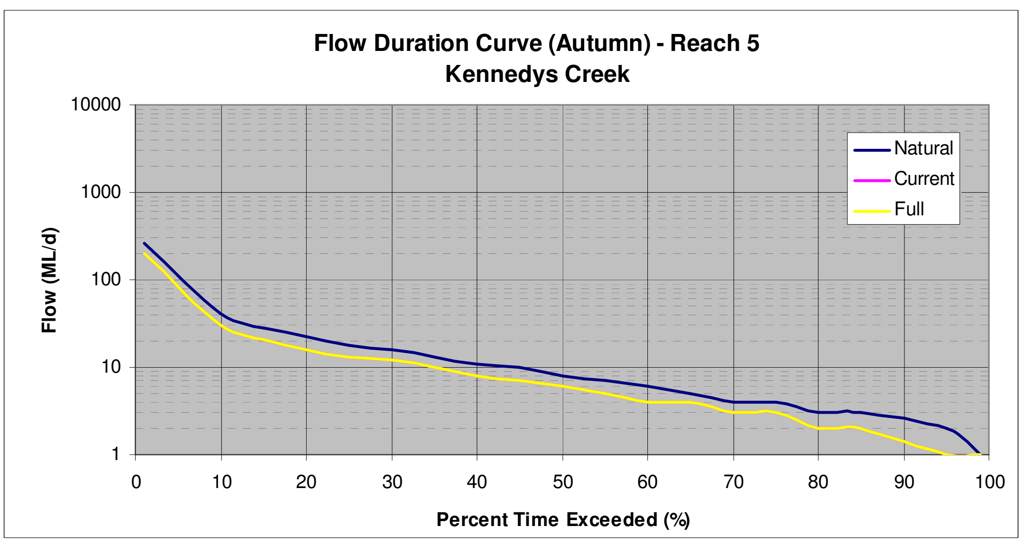
Reach 5: Kennedys Creek Catchment

Seasonal Flow Duration Curve (Summer)



Note: Current catchment configuration is equal to the full development scenario

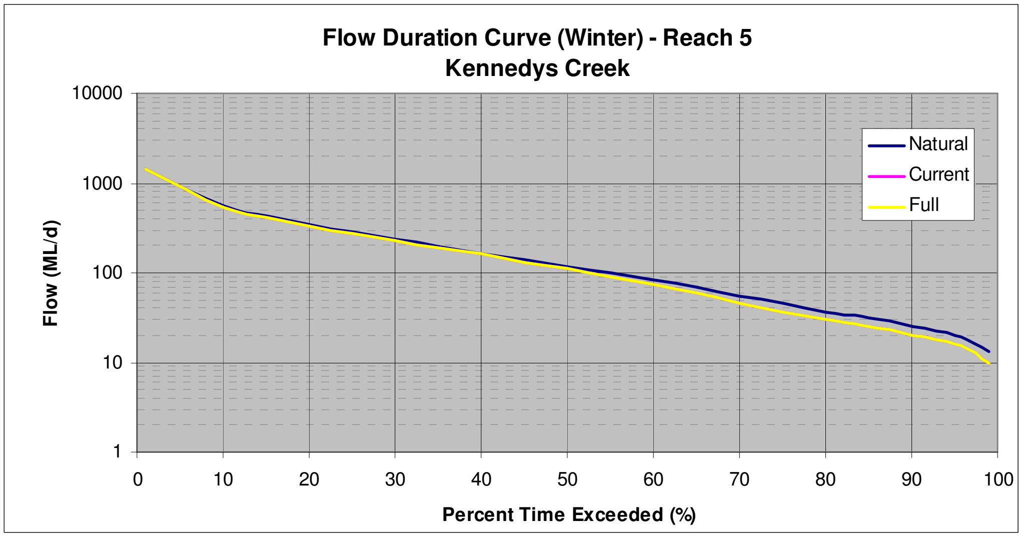
Seasonal Flow Duration Curve (Autumn)



Note: Current catchment configuration is equal to the full development scenario

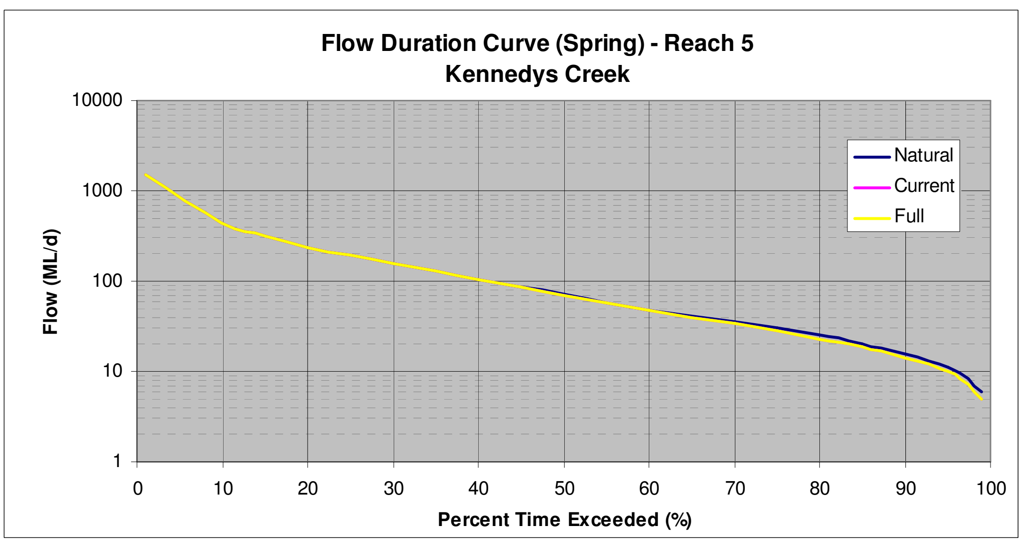
Reach 5: Kennedys Creek Catchment

Seasonal Flow Duration Curve (Winter)



Note: Current catchment configuration is equal to the full development scenario

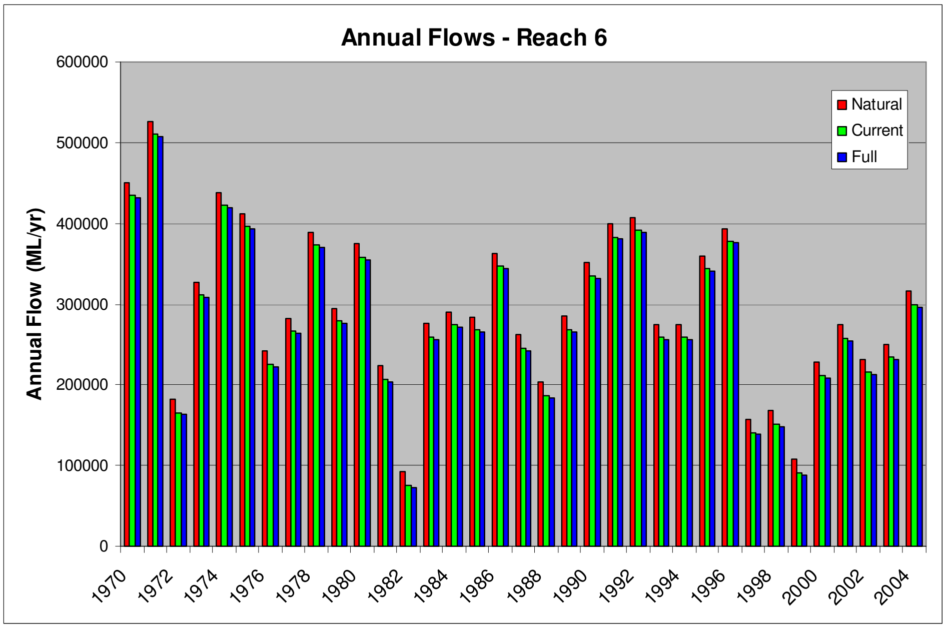
Seasonal Flow Duration Curve (Spring)



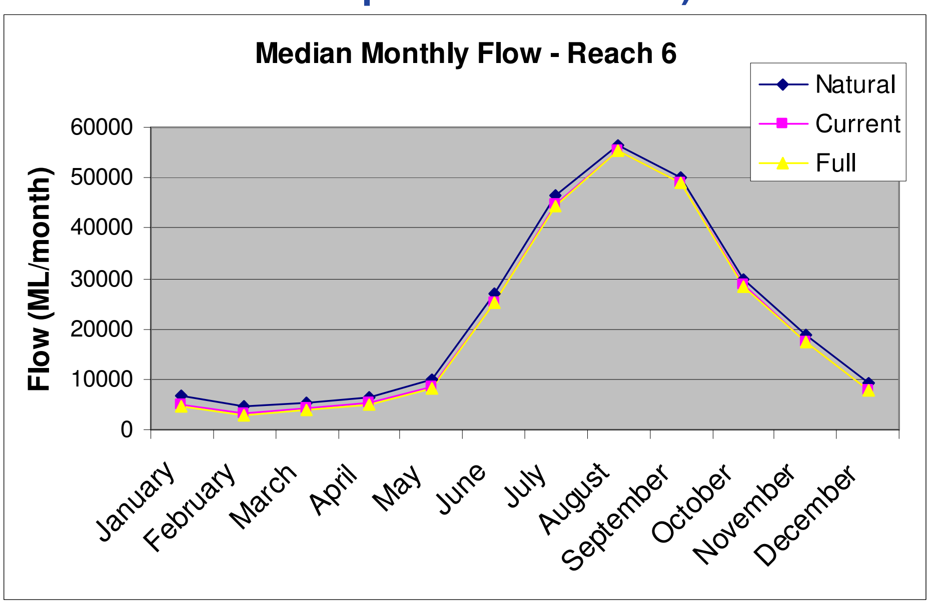
Note: Current catchment configuration is equal to the full development scenario

Reach 6: Gellibrand River Estuary

Annual Flows (natural, current and full development scenarios)

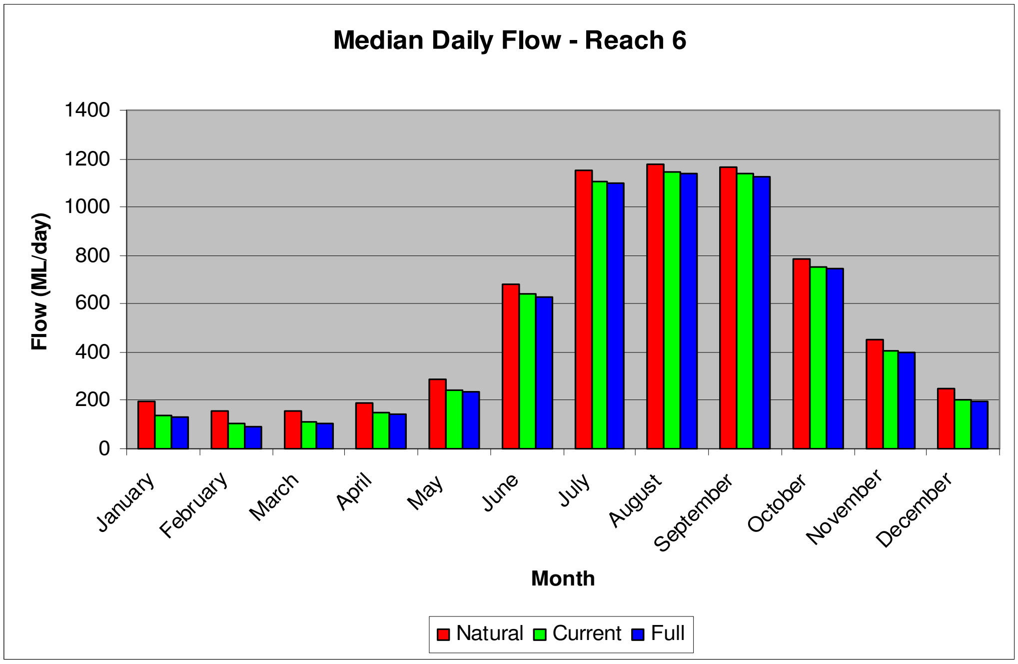


Median Monthly Flows (natural, current and full development scenarios)

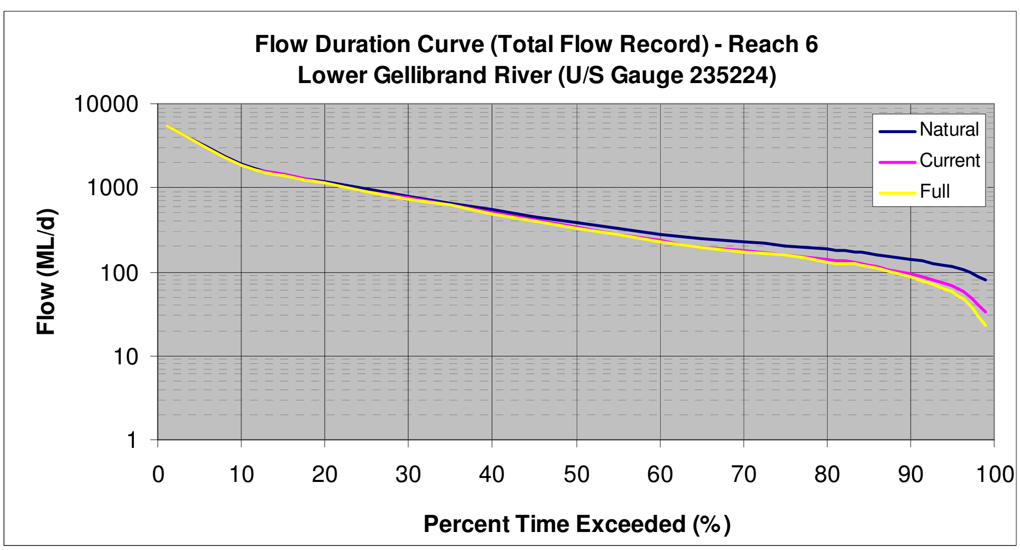


Reach 6: Gellibrand River Estuary

Median Daily Flows (natural, current and full development scenarios)



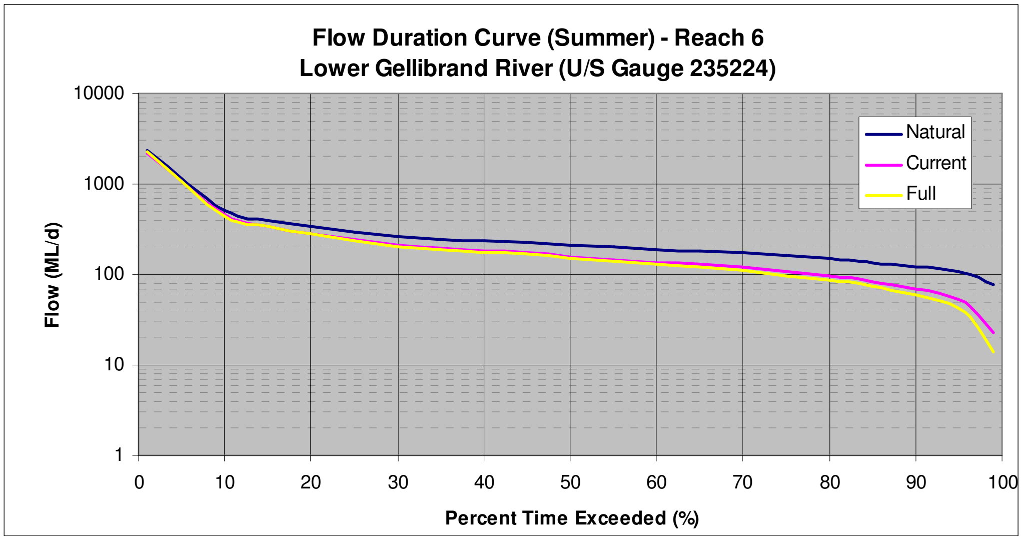
Flow Duration Curve (Total Flow Record)



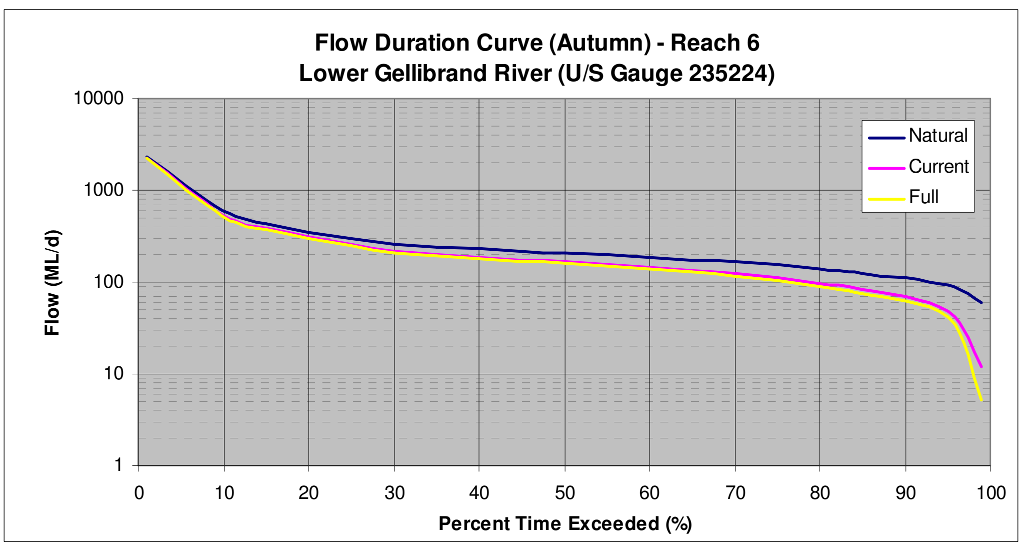
Note: Current catchment configuration is equal to the full development scenario

Reach 6: Gellibrand River Estuary

Seasonal Flow Duration Curve (Summer)

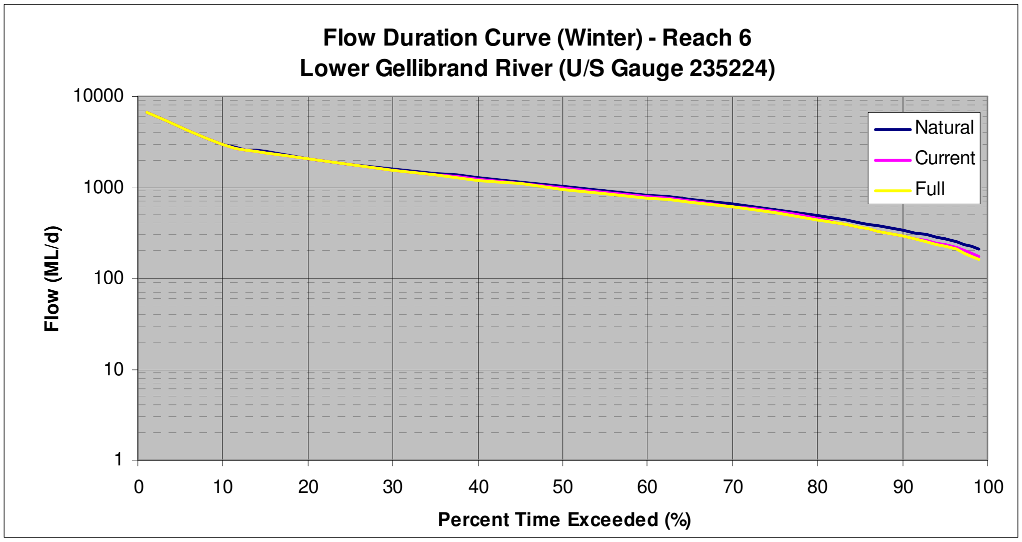


Seasonal Flow Duration Curve (Autumn)



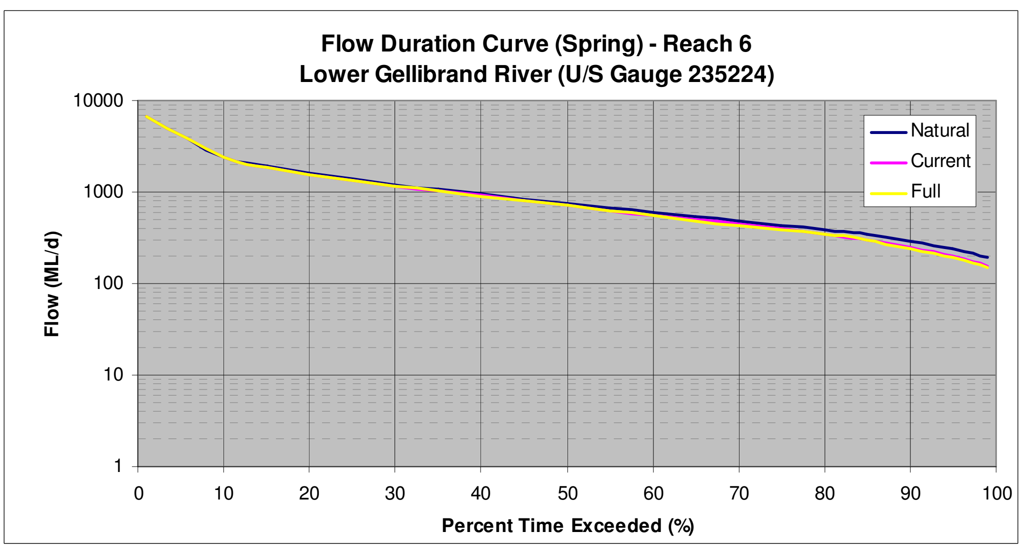
Reach 6: Gellibrand River Estuary

Seasonal Flow Duration Curve (Winter)



Note: Current catchment configuration is equal to the full development scenario

Seasonal Flow Duration Curve (Spring)



Note: Current catchment configuration is equal to the full development scenario

Appendix C
Waterway Condition and Processes
ISC results

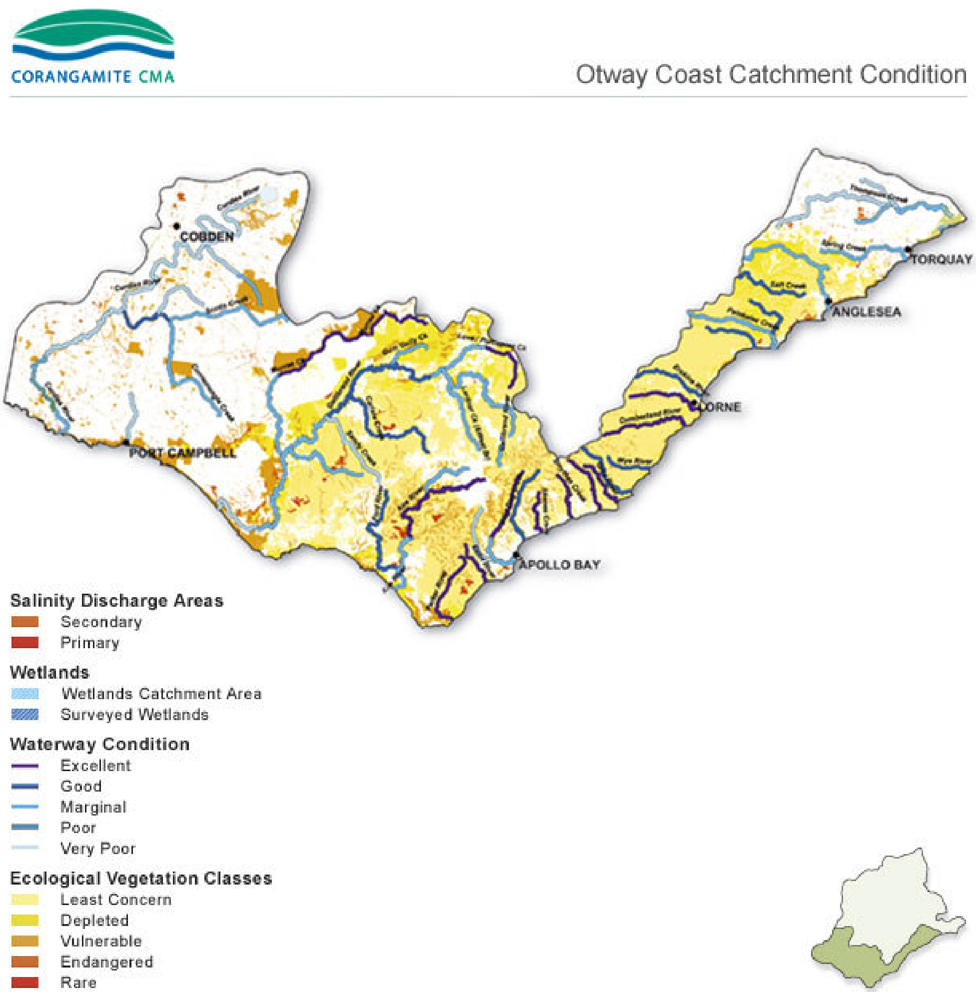
2004 Index of Stream Condition (ISC) Results

Project Reach	Basin	ISC Reach	Stream Name	Physical Form	Streamside Zone	Hydrology	Water Quality	Aquatic Life	Total	Condition
1	35	24	Love Creek	6	8	5	3		24	moderate
1	35	25	Love Creek	6	10	5			31	good
2	35	14	Gellibrand River	4	4	6	5	8	24	moderate
2	35	15	Gellibrand River	3	3	6	5+	10	21	moderate
2	35	16	Gellibrand River	6	8	6	9	9	35	good
2	35	22	Gum Gully Creek	4	9	10			34	good
2	35	23	Lardner Creek	5	3	9			24	moderate
3	35	21	Carlisle River	5	8	5	8	6	29	good
4	35	13	Gellibrand River	4	7	3	5	5	21	moderate
4	35	19	Chapple Creek	8	7	9			39	excellent
4	35	20	Sandy Creek	6	9	9			38	excellent
5	35	17	Kennedys Creek	7	5	4	3	5	21	moderate
5	35	18	Kennedys Creek	6	6	4		5+	25	moderate
6	35	12	Gellibrand River	6	3	3		6	20	moderate

Appendix D
Waterway Condition and Processes
Vegetation

	Excellent	Good	Marginal	Poor	Very poor
Flow	X				
Bed, bank, stability			X		
Streamside vegetation			X		
Water quality		X			
Aquatic life		X			

*Table 3: Current Condition of Waterways within the **Gellibrand** Catchment*



The EVC conservation status along the majority of the main stem of the Gellibrand River is EVC 18 Riparian Forest. The river passes through a number of Bioregions.

“The Gellibrand River still flows through significant areas of intact native vegetation which provide a degree of naturalness. These areas provide examples of remnant habitat and are of importance to both aquatic and terrestrial fauna. However there are ongoing threats to the river in the mid to lower sections through loss of riparian vegetation, invasion by willows and loss of stream structure caused through sedimentation. The river is a major source of urban supply for Warrnambool, Colac and many Western District townships. It also provides water resources for valuable agricultural uses, comprising, dairy, stock and domestic requirements.

Main agricultural enterprises

Grazing of dairy and beef cattle is the dominant form of land use in the catchment consisting of 298 km^2 of grazing land, with the remainder being eucalypt forest. Whilst dairying is the most common enterprise on the river flats where the irrigation licences are held, more recently there has been a rapid increase in Blue Gum plantations, in addition to the expansive area of established pine plantations.

Flow-dependant Ecological Vegetation Classes (EVCs)

Damp Heath Scrub

Estuarine Wetland

Riparian Forest

Riparian Scrub Complex

Sedgy Riparian Woodland

Swamp Scrub

Wet Heathland

Freshwater fish in the Gellibrand River catchment

Australian Grayling	*Prototroctes maraena*	Listed as vulnerable (EPBC & FFG)
Broad-finned Galaxias	*Galaxias brevipinnis*	Rare
Mountain Galaxias	*Galaxias olidus*	Insufficiently known (FFG listed)
Common Galaxias	*Galaxias maculatus*	Common
Spotted Galaxias	*Galaxias truttaceus*	Rare
Australian Smelt	*Retropinna semoni*	Common
River Blackfish	*Gadopsis marmoratus*	Insufficiently known
Short-headed Lamprey	*Mordacia mordax*	Common
Pouched Lamprey	*Geotria australis*	Rare
Short-finned Eel	*Anguilla australis*	Common
Tupong	*Pseudaphritis urvilli*	Common
Southern Pigmy Perch	*Nannoperca australis*	Common
Flat-headed Gudgeon	*Philypnodon grandiceps*	Common
Brown Trout	*Salmo trutta*	Introduced

Gellibrand Threatened Species List

Flora		***AROTS & (EPBC listed)***	***VROTS & (FFG Identified)***
Acacia nano-dealbata	Dwarf Silver Wattle		r
Acacia retinodes var. uncifolia	Coast Wirilda		r
Acacia verticillata ssp. Ruscifolia	Broad-leaf Prickly Moses		r
Amphibolis antarctica	Sea Nymph		k
Arachnorchis australis	Southern Spider-orchid		k
Arachnorchis dilatata s.s.	Green-comb Spider-orchid		k
Arachnorchis venusta	Large White Spider-orchid		r (X)
Asplenium appendiculatum ssp. Appendiculatum	Ground Spleenwort		r
Astelia Australiana	Tall Astelia	V (V)	v (L)*
Atriplex paludosa ssp. Paludosa	Marsh Saltbush		r
Austrofestuca littoralis	Coast Fescue		r
Baeckea ramosissima ssp. Prostrata	Rosy Baeckea		r
Baumea laxa Lax	Twig-sedge		r
Boronia nana var. nana	Dwarf Boronia		r
Bossiaea cordigera	Wiry Bossiaea		r
Burnettia cuneata	Lizard Orchid		r
Caesia parviflora var. minor	Pale Grass-lily		k
Callitriche brachycarpa	Short Water-starwort		v (N)
Calorophus elongatus	Long Rope-rush		v
Chorizandra australis	Southern Bristle-sedge		k
Correa backhouseana var. backhouseana	Coast Correa		v
Corunastylis ciliata	Fringed Midge-orchid		k
Corunastylis pumila	Green Midge-orchid		r (X)
Cyathea cunninghamii	Slender Tree-fern		v (L)
Cyathea X marcescens	Skirted Tree-fern		v
Desmodium varians	Slender Tick-trefoil		k
Diuris palustris	Swamp Diuris		v
Diuris punctata var. punctata	Purple Diuris		v
Eucalyptus aff. cypellocarpa (Anglesea)	Otway Grey-gum		v (X)
Eucalyptus brookeriana	Brooker's Gum		r

Eucalyptus globulus ssp. Globulus	Southern Blue-gum		r
Eucalyptus kitsoniana	Bog Gum		r
Eucalyptus yarraensis	Yarra Gum		k (X)
Exocarpos syrticola	Coast Ballart		r
Galium compactum	Compact Bedstraw		r
Gaultheria hispida	Snow-berry		e (L)
Glycine latrobeana	Clover Glycine	V (V)	v (L)
Grammitis magellanica ssp. Nothofageti	Beech Finger-fern		v
Grevillea infecunda	Anglesea Grevillea	V (V)	v
Haloragis exalata ssp. exalata var. exalata	Square Raspwort	V	v
Huperzia varia	Long Clubmoss		v
Hypoxis vaginata var. brevistigmata	Yellow Star		k
Isolepis wakefieldiana	Tufted Club-sedge		r
Juncus bassianus	Bass Rush		k
Lachnagrostis filiformis (perennial variety)	Wetland Blown-grass		k
Lachnagrostis rudis	Ruddy Blown-grass		r
Lasiopetalum schulzenii	Drooping Velvet-bush		r
Lastreopsis hispida	Bristly Shield-fern		r
Lawrencia spicata	Salt Lawrencia		r
Leiocarpa gatesii	Wrinkled Buttons	V (V)	v (L)*
Lepidium aschersoni	Spiny Peppercress	V (V)	e (L)*
Lepidium hyssopifolium	Basalt Peppercress	E (E)	e (L)
Lepidosperma canescens	Hoary Rapier-sedge		r
Limonium australe	Yellow Sea-lavender		r
Logania ovata	Oval-leaf Logania		r
Lotus australis	Austral Trefoil		k
Lycopodiella serpentine	Bog Clubmoss		r
Melaleuca armillaris ssp. Armillaris	Giant Honey-myrtle		r
Microlepidium pilosulum	Hairy Shepherd's Purse		e
Monotoca glauca	Currant-wood		r
Nematolepis squamea ssp. Squamea	Satinwood		r
Olearia pannosa ssp. Cardiophylla	Velvet Daisy-bush		v (L)
Olearia speciosa	Netted Daisy-bush		k
Olearia stellulata	Starry Daisy-bush		k
Petalochilus vulgaris	Slender Pink-fingers		r

Pneumatopteris pennigera	Lime Fern		e
Poa labillardierei var. (Volcanic Plains)	Basalt Tussock-grass		k
Prasophyllum affine	Heathland Leek-orchid	E (E)	k
Prasophyllum patens	Broad-lip Leek-orchid		r
Prasophyllum spicatum	Dense Leek-orchid	V (V)	v
Pterostylis cucullate	Leafy Greenhood	V (V)	v (L)*
Pterostylis smaragdyna	Emerald-lip Greenhood		r
Pterostylis tenuissima	Swamp Greenhood	V (V)	v
Pterostylis X toveyana	Mentone Greenhood		v
Pultenaea canaliculate	Coast Bush-pea		r
Pultenaea daltonii	Hoary Bush-pea		r
Pultenaea muelleri var. reflexifolia	Mueller's Bush-pea		k
Pultenaea prolifera	Otway Bush-pea		r
Schoenus carsei	Wiry Bog-sedge		r
Schoenus turbinatus	Top Bog-sedge		r
Stackhousia spathulata	Coast Stackhousia		k
Sticherus tener s.s.	Tasman Fan-fern		r
Thelymitra benthamiana	Blotched Sun-orchid		v
Thelymitra circumsepta	Naked Sun-orchid		v
Thelymitra epipactoides	Metallic Sun-orchid	E (E)	e (L)
Thelymitra hiemalis	Winter Sun-orchid		e
Thelymitra matthewsii	Spiral Sun-orchid	V (V)	v (L)
Thelymitra merraniae	Merran's Sun-orchid		e (L)
Thelymitra mucida	Plum Orchid		v
Thelymitra sp. aff. pauciflora (Anglesea)	Anglesea Sun-orchid		v (X)
Thomasia petalocalyx	Paper Flower		r
Tmesipteris elongata ssp. Elongata	Slender Fork-fern		v
Triglochin minutissimum	Tiny Arrowgrass		r
Xanthosia leiophylla	Parsley Xanthosia		r
Xanthosia tasmanica	Southern Xanthosia		r
Zygophyllum billardierei	Coast Twin-leaf		r

Fauna

Amphibians

Litoria reniformis	*Warty Bell Frog*	*V (V)*	*v*

Birds

Accipiter novaehollandiae	*Grey Goshawk*		*l*
Anas rhynchotis	*Australasian Shoveler*		*v*
Anseranas semipalmate	*Magpie Goose*		*e*
Ardea alba	*Great Egret*		*e (L)*
Ardea intermedia	*Intermediate Egret*		*(L)*
Ardeotis australis	*Australian Bustard*		*(L)*
Aythya australis	*Hardhead*		*v*
Biziura lobata	*Musk Duck*		*v*
Botaurus poiciloptilus	*Australasian Bittern*		*e*
Cereopsis novaehollandiae	*Cape Barren Goose*		*v*
Dasyornis broadbenti	*Rufous Bristlebird*		*l (L)*
Diomedea exulans	*Wandering Albatross*	*V (V)*	
Falco subniger	*Black Falcon*		*e*
Grus rubicunda	*Brolga*		*v (L)*
Haliaeetus leucogaster	*White-breasted Sea Eagle*		*e (L)*
Halobaena caerulea	*Blue Petrel*		*V (V)*
Hylacola pyrrhopygia	*Chestnut-rumped Heathwren*		*i*
Macronectes giganteus	*Southern Giant-petrel*		*e*
Morus serrator	*Australasian Gannet*		*v*
Neophema chrysogaster	*Orange-bellied Parrot*	*E (E)*	*(L)*
Ninox connivens	*Barking Owl*		*e (L)*
Ninox strenua	*Powerful Owl*		*e (L)*
Nycticorax caledonicus	*Nankeen Night Heron*		*v*
Oxyura australis	*Blue-billed Duck*		*v (L)*
Pedionomus torquatus	*Plains-wanderer*	*V (V)*	*e (L)*
Pezoporus wallicus	*Ground Parrot*		*v (L)*
Phalacrocorax fuscescens	*Black-faced Cormorant*		*v*
Phalacrocorax varius	*Pied Cormorant*		*l*
Platalea regia	*Royal Spoonbill*		*v*
Plegadis falcinellus	*Glossy Ibis*		*v*
Rallus pectoralis	*Lewin's Rail*		*e*
Rostratula benghalensis	*Painted Snipe*		*e*
Sterna caspia	*Caspian Tern*		*v*
Sterna nereis	*Fairy Tern*		*v (L)*

Thinornis rubricollis	*Hooded Plover*		*e (L)*
Tyto novaehollandiae	*Masked Owl*		*e (L)*
Fish			
Galaxias olidus	*Mountain Galaxias*		*(L)*
Prototroctes maraena	*Australian Grayling*	*V (V)*	*v (L)*
Invertebrates			
Archaeophylax canarus	*Caddisfly (5008)*		*r (L)*
Taskiria otwayensis	*Caddisfly (5024)*		*e*
Victaphanta compacta	*Otway Black Snail*		*v*
Mammals			
Antechinus minimus	*Swamp Antechinus*		*I*
Dasyurus maculatus	*Spot-tailed Quoll*	*V (V)*	*e (L)*
Eubalaena australis	*Southern Right Whale*	*E (E)*	*c (L)*
Mastacomys fuscus	*Broad-toothed Rat*		*I*
Miniopterus schreibersii	*Common Bent-wing Bat*		*v (L)*
Perameles gunnii	*Eastern Barred Bandicoot*	*E (E)*	*(L)*
Potorous tridactylus	*Long-nosed Potoroo*	*V (V)*	*I*
Pseudomys fumeus	*Smoky Mouse*		*e*
Reptiles			
Egernia coventryi	*Swamp Skink*		*v*

EVC Conservation Status

The majority of the main stem of the Gellibrand River is EVC 18 Riparian Forest. The river passes through a number of Bioregions.

BIOR no.	Bioregion Name	Bioregion Code	Map Unit	Map Unit Description	Cons Status	EVC geog occ	Map Unit Type	Pre1750 Area (a)	Cons Res (C)	SPZ (S)	Total Con (C+S)	Other Public land (O)	Private (P)	Unknown (U)	Total Extant Area (b)	Extant /Pre1750 (b/a)	Con Res /Extant (C+S)/b	Depletion a-b
								ha	ha	ha	ha	ha	ha	ha	ha	%	%	ha
5.2	Otway Plain	OtP	18	Riparian Forest	V	NR	EVC	2,031	102	145	247	42	514	4	807	40%	31%	1,224
5.3	Warrnambool Plain	WaP	18	Riparian Forest	V	NR	EVC	2,696	128	88	216	129	405	13	763	28%	28%	1,932
10.3	Otway Ranges	OtR	18	Riparian Forest	LC	NR	EVC	2,983	536	1,012	1,548	126	540	0	2,214	74%	70%	769

Most of the Gellibrand River's riparian vegetation is considered **'Vulnerable'**

Vulnerable status fits into the following criteria:

10 to 30% pre-European extent remains; OR

Combination of depletion, degradation, current threats and rarity is comparable overall to the above:

- greater than 30% and up to 50% pre-European extent remains and moderately degraded over a majority of this area; or
- greater than 50% pre-European extent remains and severely degraded over a majority of this area; or
- naturally restricted EVC where greater than 30% pre-European extent remains and moderately degraded over a majority of this area; or
- rare EVC cleared and/or moderately degraded over a minority of former area.

Appendix E
Waterway Condition and Processes
Estuary

Environmental Flow Needs of the Gellibrand Estuary

Objectives of this study

Investigation of the environmental flow needs of the Gellibrand estuary is an essential and complementary study to the environmental flow needs of the freshwater reaches. As Pierson *et al.* (2002) point out, the "physical behaviour of rivers and estuaries are fundamentally different which, in turn, provides a different environment for the biota and ecological systems that exist within them" (p55).

In order to determine the environmental flow requirements of the estuary, the study will be designed to review previous work to achieve the following objectives:

- Determine the hydrodynamics of the estuary, particularly the variation of salinity and dissolved oxygen characteristics with flow.
- Evaluate nutrient concentrations in the estuary and compare them to accepted water quality standards.
- Investigate the frequency of mouth closure and the impact of mouth closure on estuarine ecosystems.
- Recommend river flows necessary to preserve key features of the estuary's hydrodynamic cycle.

Hydrodynamics of West Victorian estuaries

Western Victoria has a low energy micro-tidal coast which results in highly stratified "salt wedge" estuaries (Sherwood, 1988; Bantow *et al*., 1995). In this type of estuary, salt water pushes into the estuary on a flood tide and because of its greater density, sinks below the surface (fresher) water with little mixing. This creates a situation where at any point along the estuary, 3 layers (or strata) are present – a surface "fresh" layer, a bottom "saline" layer and an intervening mixing zone of variable thickness (known as the halocline). The mixing zone thickness depends on the degree of turbulence generated by water flow or wind action. As the bottom water moves upstream, friction with the surface layer pushes the saline layer into a wedge shape – salt water thickness decreases upstream.

The region's Mediterranean climate results in a marked seasonal inequality for rainfall and thus river discharge. The length of the salt wedge varies with discharge and during high winter flows it is not unusual for all salt water to be flushed from estuaries for several weeks. During the low flow periods of summer and autumn, salt wedge length is at a maximum. Also, during low flow periods, estuary mouths become greatly reduced in cross-sectional area because there is inadequate outflow to flush sand brought into the estuary entrance as a result of coastal long shore drift.

During summer low flow periods when the mouth is greatly constricted or closed, the absence of marine exchange means that deep salt water within the wedge is not replaced. The greatly reduced mixing between surface and bottom waters means that dissolved oxygen (DO) is not introduced from surface well-oxygenated waters. If there is not photosynthesis in the deep waters (e.g. in the cases where suspended matter prevents sunlight penetration) DO is gradually reduced because of aerobic respiration, and in extreme cases, anoxia may result (Sherwood and Rouse, 1997).

Key Hydrological Features

For western Victorian estuaries, two key characteristics of the hydrodynamic cycle are particularly dependent on river flow:

(a) Winter flow sufficient to flush "aged" salt water from the estuary

Once deep water has become anoxic, it is not available for the aerobic community of the estuary. Many estuarine organisms require water of a particular salinity and with sufficient dissolved oxygen to occur at sites for spawning and egg placement or dispersal. Black Bream (*Acanthopagrus butcheri*), for example, produce free floating eggs which are neutrally buoyant in water having a salinity of approximately 15-18. Anoxic bottom waters having this salinity may become enriched in toxic substances such as hydrogen sulphide and ammonia. Eggs or larvae exposed to these waters are unlikely to survive (Sherwood and Backhouse, 1982). It is thus important that flows sufficient to remove this deep salt water are maintained in any consideration of environmental flow regimes.

(b) Adequate summer/autumn flows to maintain estuarine circulation

Fresh water flow to the sea causes mixing which removes salt water from the underlying wedge. The deep water is replaced on the flood tide and the new bottom water is itself shunted upstream as water comes in on the next tide. Thus bottom water is continually replaced in what is know as a "boxcar" circulation. Clearly, constriction of the estuary mouth reduces the effectiveness of this process and may accelerate deep water deoxygenation in turbid estuaries. Residence time of water in estuary increases. This can lead to a number of undesirable impacts on ecosystems and affects the utility of the estuary for humans. For example, mouth closure occurs with greater frequency and for longer duration as river flow is decreased. Prolonged mouth structures such as jetties and boat ramps, loss of access to farmland and flooding of roads and buildings. Mouth closure may also interfere with the migration of fish species into or through the estuary. Long periods of closure may also encourage growth in algal populations ("blooms").